Excerpts from the Circular Letters of ICOMLAC*

By
Frank R.
Moormann

Soil Management
Support Services
Technical Monograph 8
1985

*International Committee on Low Activity Clays

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SMSS is a program of international technical assistance of the Agency for International Development, executed by the Soil Conservation Service of the U.S. Department of Agriculture (BST-1229-P-AG-2178).

Excerpts from the Circular Letters of the International Committee on Low Activity Clays (ICOMLAC)

Prepared by the
University of Hawaii

for the
Soil Management Support Services

Soil Management Support Services (SMSS) is a program of international technical assistance in soil survey, classification, interpretation, and use and management of soils in the intertropical countries. It is a program of the Agency for International Development (AID) implemented by the Soil Conservation Service of the United States Department of Agriculture under Contract No. BST-1229-P-AG-2178.

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Preface

Though Soil Taxonomy (Soil Survey Staff 1975) was published in 1975, the full text was already complete in 1970 and distributed internationally. The final version of 1975 contained only minor changes. Even at the time of publication, it was recognized that the classification of the soils of the tropics was less than satisfactory due to the general lack of comprehensive data on these soils and an incomplete knowledge of the distribution of the soils. In the seventies, soil survey programs were initiated in many countries in the intertropical areas. Soil Taxonomy required several specific kinds of analyses and many laboratories were analyzing the soils according to the methods prescribed by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture.

SCS recognized that for Soil Taxonomy to be a viable system, it had to be continuously updated as knowledge grew. The system itself is constructed in such a way that changes could be made without drastic revisions in the basic concepts and the general framework of the system.

By 1975 many international collaborators felt that the Alfisols and Ultisols in the intertropical areas were too narrowly classified, confined to mainly the oxic subgroups. There was a general feeling that some taxa of this category could be upgraded with a concomitant need for new subgroups. These feelings were communicated to the SCS and also voiced at several international meetings.

The operational mechanism to coordinate such a task was a problem. SCS felt that the effort must be lead by a person with tremendous experience on such soils and that soil scientists in the intertropical areas must take the leadership to provide the inputs to refine the system as they best knew the problems and constraints of these soils. SCS was fortunate in obtaining the services of Dr. Frank Moormann, who had a lifetime of experience in the tropics and had collaborated in the development of Soil Taxonomy and who, at that time, was working at the International Institute of Tropical Agriculture (IITA) in Nigeria.

Dr. Moormann was requested to take the leadership in this task in March 1975. In order to reach as many scientists as possible, he introduced the now famous circular letters, to which interested persons responded. In 1978 the group was called a committee and formalized into the International Committee on Low Activity Clay soils or ICOMLAC. ICOMLAC was the forerunner of many other committees, or ICOM's (now numbering eight), and the format developed to run

ICOMLAC was later to be adopted by all other ICOMs.

After the formation of ICOMLAC it was soon realized that, although circular letters were productive, a forum where the members could meet and discuss was necessary. Dr. Fred Beinroth of the University of Puerto Rico took up the initiative and negotiated with the Agency for International Development (AID) to provide funds for such a forum. The first meeting of a series which has now come to be known as the International Soil Classification Workshops was held in Brazil in 1976. The tremendous success of this Workshop resulted in a second meeting in Malaysia and Thailand. With the creation of the Soil Management Support Services (SMSS) by AID, the Workshops became an integral activity of SMSS and a third workshop was organized for ICOMLAC in 1981 in Rwanda.

Every opportunity, such as other international meetings, was used to discuss the committee task. Aspects of the committee's work were published in international journals. SMSS publicized the committee as widely as possible to obtain maximum collaboration.

This monograph contains excerpts from the circular letters. The final draft proposal is currently being distributed separately. After international testing of this proposal, it will be incorporated in Soil Taxonomy.

Every person involved in this task and who has attended the International Soil Classification Workshops is aware of the difficulties involved in arriving at a proposal acceptable to the majority. The task could not have been accomplished without the leadership provided by Dr. Frank Moormann, aided by the guidance of the late Dr. Guy D. Smith.

We take this opportunity to express our appreciation to both these people, and to the many other soil scientists all over the world who collaborated so unselfishly.

This Monograph presents ideas and thoughts on a variety of subjects. It provides a picture of the evolution of concepts and the rationale behind many of the proposals. Contributors have been identified by name, though we are sure many have changed their ideas since these initial contributions. We wish to emphasize that the intent of this publication is only to show historical development--we request all readers to view it in this light and not hold any of the contributors to the opinions expressed here. The spirit of discussion was open and frank, and this monograph records a fine example of international collaboration developing an internationally acceptable soil classification system.

Hari Eswaran

Introduction

In 1975, an international committee (ICOMLAC) was constituted to study and discuss the classification of soils with a clay mineralogy characterized by a low cation exchange capacity (CEC) because of the dominance, in the clay fraction, of minerals with a low permanent charge (constant surface charge) and a relatively high pH dependent charge (constant surface potential). In the course of the committee's work, the mandate was narrowed down to the soil orders of Alfisols and Ultisols.

The present volume presents pertinent sections of the committee's circular letters, which were the main vehicle for recording the wide ranging discussions.

Reprinting of the circular letters appeared worthwhile for several reasons.

First, only a limited number of circular letters were printed, a number which bore no relation to the demand for information which has developed since the committee's inception.

Second, this collection of the circular letters offers a fair idea of the problems involved in changing Soil Taxonomy, and the way these problems were addressed by the committee and the collaborating scientists.

Third, the collection has historical value and may serve as an example of a group exercise in soil classification, with its attendant merits and faults clearly shown.

Since the letter of W. M. Johnson of March 17, 1975, news has been received from most scientists who were approached for cooperation with the committee charged to study and propose changes in Soil Taxonomy regarding classes of the Alfisol and Ultisol orders with a low cation exchange capacity (CEC): the Oxic subgroups.

Moreover, several other scientists who are or have been involved with the classification of soils in the tropics have expressed their willingness to cooperate in the activities of the committee. The efficiency and speed of our work will undoubtedly be hampered by the necessity to deal with matters through correspondence.

Though no time schedule has been set for preparing firm proposals, I feel that we may be able to submit something worthwhile during the coming years if we limit our discussions to the specific points mentioned in J. McClelland's letter of March 27, 1975 to me. Thus, inevitably, some "ground rules" should be set forth, which I am now submitting to you while drawing your attention also to the "Procedures for Amendments" which SCS sent us.

1. The primary objectives of Soil Taxonomy "Procedures for Amendments" are clear, and should guide the work of the committee. In particular objectives (3), "retain, as far as practical, the groupings currently used," and (4), "define the limits of each class as objectively and precisely as possible," will require our continuous attention.

   By the same token, the committee should work within the framework of the philosophy and mechanism of Soil Taxonomy as it now stands. Any changes proposed should be consistent with the framework of the present Soil Taxonomy and should follow the set of rules which determines the definition and nomenclature of all classes.

2. While it is of extreme importance to establish relationships with other national or international soil classification systems, this is not the prime purpose of our work. I would suggest that rather we try to find out how far precisely defined individual soils from other systems can be fitted into Soil Taxonomy. We can and should use the field and laboratory data on soils classified in other systems to see where they fit in Soil Taxonomy, but we should be specific.

3. Whenever possible, proposals for changes in diagnostic criteria and for the introduction of revised and new classes should be accompanied by supporting evidence. In this respect field descriptions of soils under discussion, analytical data (with special reference to those now in use as diagnostic criteria in Soil Taxonomy), and detailed soil maps and excerpts of such maps would be extremely useful. It is suggested that such materials may be assembled and collated through the office of the chairman.

4. In order to facilitate procedures it is suggested that the chairman, by means of circular letters, inform the members and other cooperating scientists of reactions, data, and proposals made. Most correspondence would thus go through the chairman, but it is hoped that during meetings and in private correspondence many of us will be able to discuss the problems at hand. It would be appreciated if the chairman could be informed of the results of such correspondence and discussion.

In the first circular letter I would like to make some remarks on the problems which concern our committee, which are briefly outlined in J. McClelland's letter of March 27, 1975 to me. When the tropics are considered as a whole it is evident that Soil Taxonomy classes as they now stand do not really cater at a sufficiently high level to soils with a low CEC, i.e. soils of which the subsurface horizons have a clay complex largely dominated by kaolinite and sesquioxides (mainly Fe oxides, hematite and/or goethite). With the exception of the Oxisol order such soils are only found in the classification at the subgroup level as "Oxic" subgroups. To cite an example: the potential for use and management of tropical (oxic) Haplustalfs is certainly sufficiently different from temperate Haplustalfs, like those found on the Great Plains in the U.S., to warrant their separation at a higher level. Moreover, the present mechanism does not provide for much leeway to introduce relevant subgroups. Thus, the larger part of the well drained soils in the savanna and dryer forest zones of W. Africa would fall under one subgroup, i.e. Oxic Paleustalfs, even though they are often not physiographically related, nor do they have much similarity in morphology. Distinguishing their common characteristic, that of a low activity clay in the appropriate diagnostic horizon, at a higher level, would open the possibility to introduce more meaningful subgroups.

Low activity clays are most common in the tropical and subtropical belts, but they are also found outside of the tropics. G. D. Smith, during a recent discussion I had with him, remarked that low activity clays occur as far north as New York State. It is clear that such northern (or, for that matter, southern) Oxic subgroups do have a very different potential for use and management than the tropical Oxic subgroups, where, temperature-wise, the growing cycle is not interrupted. He therefore proposed that in our work on Oxic subgroups in the tropics we should introduce the temperature regime as a diagnostic criterion, including only soils with a thermic or warmer, or an isomesic or warmer, temperature regime. This would probably exclude the "oxic" soils from temperate climates, while, at the same time, not excluding the soils of tropical highlands (as in Kenya). This will have to be tested, however, the introduction of an appropriate diagnostic criterion based on temperature should not offer too many difficulties.

Low activity clays are found in several orders, the primary one being the Oxisol order. In my discussions in Washington D.C., however, it was tentatively decided that the immediate mandate of the committee should cover only the Alfisol and Ultisol orders, with the specific exclusion of the Oxisols. It appears that the definition of the oxic horizon and, more specifically, the implied requirement that such a horizon should have less than the 1% cutans that indicate "active" clay translocation excludes many soils that, based on incomplete data, hitherto have been considered as Oxisols. I may mention that very few (if any) Oxisols were found by me and other workers in W. Africa. The French "Sols ferrallitiques" of that area, as well as the "Ferralsols" of the FAO/UNESCO map, are not equivalent of Oxisols--mainly they are Ultisols and Alfisols. On the other hand, J. Bennema from The Netherlands indicates that in S. America, and more particularly in Brazil, large surfaces of Oxisols occur.

However this may be, it is suggested that the discussion of the classification of Oxisols should either form the mandate of another committee or that it should only be discussed in our committee at a much later stage. The Oxic subgroups in other orders, e.g. Inceptisols, are not proposed for discussion at this stage, although I would like to discuss the "Oxic" Mollisols in a later letter, mainly with the view of excluding them from that order.

Having thus limited ourselves to the tropical soils (in terms of temperature regime) with low activity clays (in terms of CEC) in the Alfisol and Ultisol orders, I would like to make some suggestions on subjects which, in my opinion, might be given early attention in our discussions.

A. In regard to diagnostic properties

1. By far the most important diagnostic property of the present Oxic subgroups is the CEC of the major part of the argillic horizon, which has to be less than 24 meq/100 g clay as determined by the method with NH_4OAc, buffered at pH 7 (Soil Survey Investigations Report No. 1, Method 5A1. SCS). I underline this method because it is becoming increasingly clear from studies of the pH-dependent surface charge properties of low activity clays that CEC values for 100 g clay vary widely around the critical 24 meq value according to the method used.

   For the soil material in the "Oxic" subgroups having a small or negligible permanent charge, CEC values fluctuate to an important extent with the pH and with the concentration of the salt solution employed for the measurement. Though pH dependency of the CEC is also found in clays with the more active 2:1 layer lattice clays, variations in CEC values in low activity clays are relatively much greater. Thus, in such clays, the CEC measured at pH 7 may be (and often is) twice, or more, as high as the CEC measured at the pH of the soil, if this pH is considerably lower than 7. G. Uehara, who has much experience on "both sides of the fence," i.e. in the chemical behavior of low activity clays and in the classification of soils with low activity clays, will undoubtedly comment.

Therefore, we wish to classify specific soils in regard to their being "oxic" or not, supporting evidence should include CEC data as determined by the above method. In order, however, to be able to use or to interpret existing data, like those of Zaire assembled by C. Sys (Charactérisation morphologique et physicochimique de profiles types de l'Afrique Centrale, INEAC 1972), it is suggested that the CEC of a sufficient number of low activity clays be determined by both the standard NH_4OAc method and by the method in use in the current national and international soil survey and classification programs. This way it may be possible to establish correlations between CEC values determined by various methods.

I know that such studies on selected samples are currently under way at the International Institute of Tropical Agriculture (IITA), Ibadan, in cooperation with the laboratory of the Land Resources Division, ODM, Reading, U.K. and with the University of Louvain, Belgium. C. Sys informed me that he is currently re-analyzing a number of his Zaire samples using the two methods of Soil Taxonomy. I may also refer to Appendix 4 of "Classification of Brazilian Soils" by J. Bennema (FAO-EPTA Report 2197, Rome 1966) where the correlation is discussed between the "sum of cations" method of Soil Taxonomy (Soil Survey Investigation Report No. 1 Method 5A3a. SCS), with determination of the exchange acidity by displacement with $BaCl_2$-triethanolamine (TEA) at pH 8.2, and the method in use in the Soil Survey of Brazil, exchange acidity with extraction by 1 N calcium acetate at pH 7. Other comparative studies possibly have been or are being made and I suggest that it is of the highest importance that our committee considers such studies.

2. The whole question of CEC and the derived value of base saturation is equally important when considering the separation between Alfisols and Ultisols. Indeed the most crucial differentiating criterion for distinguishing between the two orders is the base saturation, which is more than 35 percent for Alfisols and less than 35 percent for Ultisols, the CEC having been determined by the "sum of cations" method mentioned above.

Base saturation being inversely related to CEC, we also run across the same problem when using this value as a diagnostic characteristic, and this especially of course in the soils dominated by low activity clays which are the primary interest of our committee. Fortunately, it appears that in the field a majority of the tropical soils that interest us either has a high saturation or a very low one; but there are transitional areas with "critical values" for saturation. In such cases, the method used for CEC is critical, and for such soils the CEC determination according to the "sum of cations" method of Soil Taxonomy should be given as a necessary item of information.

B. In regard to definitions of classes

1. One of the most important aspects which the committee will have to give attention to is the level in Soil Taxonomy at which "oxic" Alfisols and Ultisols should be distinguished. At present, as discussed before, the level is that of the subgroup, though there are a number of great groups which are comprised mainly of soils with low activity clays.

If we admit that in the two orders under question the suborder level is mainly reserved for separation based on the soil moisture regime, then the two levels that "Oxic" subgroups could be elevated to are respectively the order and the great group.

Recognizing the low clay activity properties at the order level has been suggested at various times. The present French and Zaire (INEAC) classifications do this to a large extent, and, in practical fact, the classification of S.E. Asian soils by Dudal and Moormann, used in several countries of that area as the basis of national soil classification systems, often groups soils with low activity clays, irrespective of base saturation (e.g. Gray Podzolic Soils).

In his letter of acceptance as a member of our committee, C. Sys specifically re-submits this proposal: "in my mind Ultisols and Alfisols should be separated according to the CEC of the clay; all soils with a clay fraction having a CEC of less than 24 meq/100 g clay and an argillic horizon should be called Ultisols." Strictly in terms of classification, this solution, when temperature restrictions are also included, would facilitate matters considerably, though the implications for the whole structure of Soil Taxonomy would be far reaching. If I understand Sys' proposal correctly, base saturation would be dropped altogether as a criterion in two orders. An alternate to Sys' proposal might be to amend the present definition of Ultisols in such a way so as to include soils which either have a base saturation (BS) of less than 35 percent (CEC sum of cations), or a CEC of less than 24 meq/100 g clay, (CEC NH_4OAc, pH 7), or both.

The distinction of the oxic character at order level has, on the other hand, certain aspects which are not in line with the primary objectives set forth in the "Procedures for Amendments." A considerable number of dominant soils, specifically Ustalfs and Xeralfs in the dryer part of Africa (Sahel and Sudan zones), would become Ultisols, even though a number of them have not only high base saturation but also may contain free $CaCO_3$ within the solum. What this boils down to is that though the clay fraction of such soils have lost most, if not all, of the 2:1 layer lattice clay component (if they ever had it), the solum is not in its ultimate stage of chemical weathering.

This is corroborated by the fact that many Ustalfs and Xeralfs belonging to the "Oxic" subgroups contain considerable amounts of weatherable minerals in the fine sand and coarser fractions if these soils are found on parent materials containing such minerals (e.g. gneisses and mica schists of the Pre-Cambrian Basement Complex in West Africa). This trend appears to go against the first objective of Soil Taxonomy. Moreover, our recent studies of management--soils sequences in W. Africa--appear to point to the fact that the second objective of Soil Taxonomy is best met by the present Alfisol-Ultisol separation. Certainly, in terms of low management level production of major foodcrops on the well drained components of landscape, the Alfisol-Ultisol distinction of soils with low clay activity is reflected in the potential of the soils and their suitability for specific crops.

I do submit the proposal of C. Sys for specific discussion and comments, the above being my own initial contribution to the discussion.

The proposal to elevate the Oxic subgroups of the Alfisols and Ultisols to the great group level is the one summarized in J. McClelland's letter to me. This proposal has, in my opinion, the advantage that it would affect the present structure of Soil Taxonomy to a lesser extent while at the same time highlighting the low clay activity character, which is important from morphogenetic, soil geography, and potential-management points of view. At present, I will not go further in detailing the excellent summary of this proposal given by McClelland, but I would submit it side by side with the Sys' proposal for your consideration of "pros and contras." If we do reach a certain consensus the next step would be to describe the impact of this particular amendment on definitions of all taxa that will be affected.

2. Once the question of the "level" of recognition is settled, the next and most important question would be to decide upon meaningful subgroups within the framework of the mechanisms set forth in Soil Taxonomy for such subgroups. In certain cases the subgroups may reflect the original great group from which the oxic subgroup is separated. As an example the present Oxic Paleustalfs and Oxic Haplustalfs which meet the proposed temperature regime requirements might become respectively Typic Oxiustalf* (being the most common representative) and Haplic Oxiustalf (having a textural profile which excludes it from the typic subgroup). The regrouping into "Oxi" great groups should, however, at the same time be used to establish new subgroups, probably even using new sets of diagnostic criteria, so as to make Soil Taxonomy more useful for the tropical and subtropical zones.

In this respect, I submit as an example, the presence or absence in the solum of weatherable minerals in the 20-200 micron fraction is a characteristic in "Oxic" tropical soils which is worthwhile to be distinguished at the subgroup level, rather than at the family level. Indeed, in view of rapid tropical weathering, the inherent nutrient behaviour of, say, Typic Oxiustalfs (at present Oxic Paleustalfs) on most areneceous sedimentary parent materials in W. Africa is quite different from that behavior on materials derived from many igneous and metamorphic rocks. Whereas in the former the 20-200 micron fraction is composed almost exclusively of quartz, in the latter weatherable minerals are common.

* Tentative nomenclature, later abandoned.

This particular case is just given as an example of where we may want to go in our work on subgroups and of what kind of criteria we may want to test. I hope to receive and discuss others in due time.

Circular Letter No. 2, December 1975

I would like to start this letter with a number of "housekeeping" matters.

1. To date, comments and opinions on the points raised in the previous correspondence were received from:

   G. D. Smith, whose most important and basic contribution I append to this letter for discussion and for comments from you.
   R. F. Isbell, CSIRO, who will replace H. Haantjens as the Australian member.
   A. Van Wambeke, as yet writing from Ghent in Belgium.
   G. Uehara, whose proposal on the name of the committee was adopted.
   S. Buol, with whom I had, in late November while he was visiting Ibadan, a few most useful sessions on points of interest to our committee.

   Letters, mostly accompanied by relevant publications, were received from M. Leamy, C. Sys, W. Sombroek, and M. Camargo; the last two have also sent samples of "genuine" Oxisols for ongoing research on low activity clays at IITA. Notes were received from G. Aubert and P. Segalen, both from ORSTOM, with promises of relevant published and unpublished documentation (not yet received). It would be tremendously appreciated if those who have accepted the invitation to serve on our committee and with whom I have had as yet no written contact would please write to me at my address in the Philippines (where I will be spending most of my sabbatical year). Pour nos membres francophones: votre président acceptera volontièrement vos communications en langue francaise.

   Several colleagues have shown interest in cooperating with our committee, to wit: P. Segalen and G. Aubert from France, and J. Bennema from The Netherlands. R. Dudal, FAO, Rome, was contacted, and sent welcome comments on circular letter no. 1, with special reference to the FAO/UNESCO soil units.

Constructive comments on the desirability of the committee meeting were given by G. Uehara and M. Leamy. Uehara proposed that support should be sought from international granting agencies to enable the committee to meet as a group. Leamy suggests several avenues to solicit grants. I have not approached any possible granting agencies but will do so early next year, while at the same time suggesting that our parent body, SCS USDA, might comment on the feasibility of such a meeting. A tropical environment would be conducive, and in this respect I suggest one of the international institutes (IITA, CIAT, ICRISAT, or IRRI) as the place of venue. As it is, several of us will meet at the University of Hawaii-organized soil seminar at ICRISAT, Hyderabad, India, in January, and there I hope to discuss committee matters.

2. I would like to use the second part of this letter to discuss some of the points raised in the letters received, trying to outline a few points of consensus (which, as G. Smith remarks, is all we can hope for), and a few essential points where there is such a lack of agreement that further discussions are required.

A. Distinction Alfisol-Ultisol

The comments on the proposal to use clay activity per se to define these two orders were virtually in agreement, and not in favour of the Sys' approach mentioned on page 7 of circular letter no. 1. High versus low base saturation, used for the Alfisol-Ultisol separation, is too important a parameter in evaluation and management to warrant a basic change of principles.

Another matter is the 35 percent base saturation limit between the two orders, with the CEC determined by the $BaCl_2$-TEA method as is done in Soil Taxonomy. As I understand it, this method of CEC-base saturation determination was used in Soil Taxonomy because by far the largest part of available analytical data was done according to the $BaCl_2$ CEC method, and because these data gave the best "fit" with field observations. Comments in various letters are clear: for low activity clays, this method is not satisfactory because of the relatively high increase in net negative charge due to high salt concentration and high pH value of the displacing solution. It would not be so bad if values for CEC, determined by several and all methods could be correlated, but unfortunately this is not nearly always the case. S. Buol has sent extensive material on this (which arrived with much delay), while R. Isbell also discusses the point to some detail. His chemist colleague, G. Gillman, suggests that as an alternative to using CEC (and base saturation) a more fundamental property such as zero point of charge be considered. T. Juo, our IITA chemist, has just finished a study on selected low clay activity argillic horizons of Alfisols and Ultisols in S. Nigeria and has given permission to quote the results from a curvelinear regression analysis of base saturations (BS), calculated from three methods for CEC, as follow.

1. $(BaCl_2\ BS) = -10.67 + 1.95\ (Acetate\ BS) - 0.016\ (Acetate\ BS)^2$

$$R^2 = 0.609$$

2. $(KCl\ BS) = 5.28 + 2.13\ (Acetate\ BS) - 0.012\ (Acetate\ BS)^2$

$$R^2 = 0.919$$

While the relationship between the $BaCl_2$ and acetate methods is rather poor, the correlation between the KCl and acetate methods is very good. In this case, a 50 percent Acetate BS is an 80 percent KCl BS for low activity clay argillic horizons with pH-H_2O varying from 4.5 to 6.1. Some of the data from S. Buol appear to reasonably fit the equations. One thing seems certain: this matter should go back to the drawing board, i.e. to the soil chemists, if we are to have internationally usable solutions.

S. Buol and I came to a very tentative working proposal to make the Alfisol-Ultisol separation more flexible by adding to the present definition another critical BS value of: 50 percent, if CEC determination is by acetate extraction. There would, no doubt, occur some overlap, but, according to our present studies in W. Africa, the number of soils involved would be small.

For the sake of brevity we will refer to this CEC as $BaCl_2$ CEC, to neutral NH_4OAc displacement as acetate CEC, and to unbuffered 1 N KCl extraction as KCl CEC. The corresponding base saturation values are indicated as $BaCl_2$ BS, acetate BS, and KCl BS.

B. Definition and nomenclature of low activity clay great groups

I will propose here that we proceed on the assumption that such groups are going to be introduced. Only from S. Buol was an initial comment received which "challenged" the desirability of such great groups, but our recent discussions and exchanges of our experiences have clarified the situation.

Some proposals for "keying" out the low activity great groups were received; I feel that more definite proposals have to wait until all have Soil Taxonomy available and have had the chance to offer their input. The main points from G. Smith's letter for immediate discussion are:

1. That the control section be the upper 50 cm of the argillic horizon. My own reaction is in favour of this proposal. We have indeed found one or two soils where the saprolite had higher clay activity due to presence of smectite, however, these cases were extremely rare.

2. That some other prefix is used instead of "Oxi." I am quite open to any suggestions. In this context some comments by R. Dudal are relevant. He writes: "Another remark which I should like to make is that we (i.e. for the FAO legend), have preferred the adjective "ferric" connotive of the "sols ferrugineux" for soils with an argillic horizon rather than oxic."

   Unfortunately this link is not exclusive because most "sols ferrallitiques" in W. Africa also have an argillic horizon. Nevertheless, the use of the prefix "fer" or "ferr" as in Ferrustalfs might be considered. This name, in our case, would then have no specific connotation; although it may be argued that Fe oxides form an important part of the clay fraction of low activity clays. Comments, please: we will have to decide on a name and, unless other proposals for a usable prefix are coming up, the choice would now be between "oxi" and "ferr."

C. The temperature regime question and the related question of the "trop" great group

The opinions on this subject are very divergent. G. Smith's viewpoint is clear from circular letter no. 1 and from his letter in response: maintain the "Trop" great groups in the udic climates and introduce a temperature regime limit for the low activity great groups. A. Van Wambeke would, in the context of our work, like to expand the "Trop" great groups so as to include the ustic suborders of Alfisols and Ultisols. To save time, I would mention here the rationale that G. Smith gave me for not having "Trop" great groups with an ustic (or dryer) soil moisture regime: the dry season when plant growth virtually stops plays the same role as the cold (freezing) season in higher latitudes, hence the "Trop" great groups in Ustalfs or Ustults would be redundant. The third point of view is from S. Buol, who, in writing and in our discussion, made it clear that he totally disagrees with "introducing temperature ... at a high level in Soil Taxonomy." He cites the example of his work in the Amazon basin of Peru, where he finds Paleudults and Rhodudults (keyed out on non-temperature characteristics) side by side with Tropudults (keyed out on the temperature regime). This difficulty, of course, was also found in our W. African work and has been a cause of great dissatisfaction. To bring the problem back to our terms, reference the Buol proposal, would be to leave temperature regime completely out of the definition of the low activity great groups.

For those working in the tropics I would suggest that this is easily acceptable, but I can hear the howls of State-site classifiers who would have to "cope" with low activity Great Groups as far north as New York State. Yet a decision on this point is clearly necessary if we are to make progress, and I would urgently solicit comments and guidelines from the SCS in this respect.

3. These are the main points, but there are some others which I would like to touch upon at this time, and on which your opinion is requested.

   a. Should or should we not include Oxisols in our discussion? My opinion is that, at this stage, we should not; but some, e.g. G. Uehara, want to consider the problems of low activity clays as a whole.

b. The validity of the 2.5 times 15 bar water as an estimate for clay (needed to calculate CEC/100 g clay). This validity is doubtful according to recent work in Hawaii and in our W. African soils. Fortunately we have had not too much trouble with dispersion, using ultrasonics in cases where dispersion was difficult with "classical" methods.

c. R. Isbell reports on the difficulty of identifying translocated clay in the low activity clays and, hence, the difficulty in diagnosing an argillic horizon. This I think is a rather general problem in udic and perudic climates, like those in Malaysia and the wet parts of Africa, where a vigorous forest vegetation has destroyed cutans in the upper part of the argillic horizons. Soil Taxonomy says that we should in these cases look for cutans in the lower part of the argillic horizon, and that is exactly what we are now doing in S.E. Nigeria. S. Buol, running across the same difficulties in S. America, gives strict priority to the "more than 1.2 clay ratio" between the A and the underlying supposedly argillic horizon.

d. If and when we start keying out the low activity great groups, I can foresee difficulties with the "Plinth" great groups. My comment here: while during my 20 tropical years I have found and described quite a few Plinthudults, Plinthustalfs, etc., the distinction of plinthite at such a high level has never been satisfactory to me. It is, in my opinion, a subsidiary soil material characteristic, the value of which as a diagnostic characteristic is confused by the fact that all sorts of transitions between the fully hardened (laterite) and the still soft (plinthite) forms exist vertically in profiles and even laterally in the same horizons. A characteristic, moreover, which would take more than a year or so to establish with certainty, is not a very good one for a surveyor; and yet this is in most cases what one has to do--only exposure of an alleged plinthite will ascertain whether or not it will harden irreversibly. Hence, my proposal to leave "plinth" great groups altogether out of the Alfisols-Ultisols, relegating them to the subgroup level or even to the family level.

Circular Letter No. 3, March 1976

A. General

During the last three months I have mainly been travelling in various countries of Asia. One advantage of this is that considerable time could be given to discussions in India, Indonesia, and Malaysia with committee members and other colleagues, and to field examinations, of some soils which fall under our mandate. With F. Beinroth, G. Uehara, and J. Bennema a discussion session was held at Hyderabad, India, in January and committee business was also discussed with W. M. Johnson of USDA.

The discussions that M. Leamy had with soil scientists attending the Third ASEAN Soil Conference, 26 November-5 December, 1975, in Malaysia, should be acknowledged here. In Thailand, Malaysia, and Indonesia, I found a keen interest in what we are doing. It should be mentioned that several pedologists from the area, who want to use Soil Taxonomy, are anxious to find ways and means to bring their ideas to the attention of the appropriate authorities.

Following remarks of some committee members the committee's title was again revised. The latest title implies that we are not dealing with soils dominated by low activity clays belonging to other orders.

B. G. Uehara's contribution

Various contributions have been received since circular letter no. 2 and the erratum of December 18, 1975. While all are important, I have this time selected G. Uehara's discussion on soil properties accessory to low activity clays to be appended to this letter for your information and comments. My own tentative comments pertain to the list of soil properties given as an enclosure. Some of the characteristics given for low activity clays are relevant for soils with a high content of constant potential sesquioxides (e.g., typical for soils from volcanic rocks, as in Hawaii). But many of the soils we are working with are strongly dominated by constant charge phyllosilicates, mainly kaolinite, and such characteristics as high phosphate fixation, low crusting, high aggregate stability, positive or zero delta pH do not hold for these soils. This, at least, is our experience in most of the West African soils with low activity clays, especially those in the Alfisol order on materials derived from metamorphic and sedimentary rocks. While I deem myself not competent to discuss to any depth the basic colloid chemistry and clay mineralogy involved, I would like to point to the importance of the management implications as regards the "sesquioxidic" versus the "kaolinitic" soils with low activity clays. Of course, this difference is (frequently) reflected at the family level in the mineralogy classes--but, should it stay there?

C. The argillic horizon

Further comments and pertinent data were received regarding the definition of the argillic horizon and its use as an important diagnostic characteristic in the separation of Alfisols and Ultisols from other taxa (circular letter no. 2, point 3c). It appears that clayskin requirements (Soil Taxonomy, pp. 21-24 and p. 27, sub 4 and 5) to diagnose an argillic horizon are not met within many of the low-activity clay Ultisols in the wetter equatorial udic and perudic climates. M. Cline indicates that this phenomenom is not unique to soils of low-activity clay; nevertheless it seems more general in such soils. A clearly diminishing occurrence of optically visible clay movement occurs, for instance, in the Thai-Malaysian Peninsular, going from areas with a more or less pronounced dry season to perudic areas where no prolonged drought occurs during any part of the year. In Sarawak (J. Andriesse's Ph.D. dissertation, Royal Institute of the Tropics), W. Java, and S. Sumatra (current work of P. Buurman at the Bogor Soil Research Institute), many of the "Red and Yellow Podzolic Soils" do not optically seem to have clearly defined clay skins. Work in the Malaysian Peninsular (Eswaran, Law Wei Min, et al.) points in the same direction, as does recent work in a "climosequence" of soils on crystalline Basement Complex rocks in Nigeria. In S. America absence of clearly defined cutans or visible clay movement has been reported by, among others, S. Buol (for Udults).

Within a given udic or perudic area there may be differences related to particle size distribution, origin and nature of the parent material, and other factors. Thus, near Kuala Lumpur, the Serdang series on argillaceous shale has no clay skins detectable in thin-sections, while the Rengam series from granite has patchy Clay skins on some peds and in many pores. Landforms indicate that the age of the particular landsurface is not very old, possibly it is even quite young. Similar findings were made in S.E. Nigeria and the adjacent wet portions of the Cameroons. I am sure that other examples will be forthcoming.

The trouble is that, in many cases, the occurrence of clay skins is taken as a "conditio sine qua non" to diagnose an argillic horizon; when, in reality, this is not so according to Soil Taxonomy. The absence of clay skins in the zone of active rooting in soils on very old, stable, forested surfaces is mentioned in Soil Taxonomy (pp. 23-24). It may be suggested to waive the "very old, stable" part of this phrase for isohyperthermic, udic to perudic, climates, where the same thing is found under luxuriant equatorial forest on surfaces which are neither very old nor very stable. Moreover, and I quote verbatim, Soil Taxonomy states (p. 24) "it must be emphasized also that many argillic horizons have few or no clay skins and that other features, which are discussed later, must be used for identification of these horizons." Indeed, in most cases, the texture requirements for the argillic horizon seem to be met even if the clay skins are absent or not readily detectable. Subsidiary characteristics such as the structural instability in the surface horizons, the presence of bleached mineral grains, etc., may be used to "save us" from classifying soils such as the Serdang series of Malaysia as Oxisols.

G. Smith treated the subject in considerable detail and I submit his discussion and proposal to the committee. The temperature requirement in his proposal will be further discussed under point E. of this letter.

G. Smith writes:

> We have been forced to identify argillic horizons because they are diagnostic for Alfisols, Ultisols, and Oxisols. Yet, as I pointed out in the definition of the argillic horizon, it is not important in itself. It is the accessory properties that are important. North Carolina studies have shown that the ped coatings of the argillic horizon of at least some Ultisols are quite unlike the ped interiors, being higher in nutrients that are cycled by plants. In many Ultisols the roots do not enter the peds but are in contact only with the ped coatings. In most oxic horizons the basic structure is granular, but the peds are extremely small and very strong. They are too small for roots to enter and the coatings seem to be mostly of

iron. While some Oxisols do have a secondary blocky structure with cutans, the intent was to exclude them from typic subgroups.

If the structure of a B horizon is blocky or primatic the nutrients cycled by plants will tend to be concentrated on the ped faces because the water carrying the nutrients tends to move along these faces. Such a horizon should behave like an argillic horizon with respect to the roots even though we can find no clay skins. We can reduce emphasis on clay skins in the definitions of the soils that concern us very easily. Without changing the definition of the argillic horizon we can modify the definitions of Alfisols and Ultisols to include the soils we want, just as we waived the presence of the argillic horizon in Alfisol and Ultisols that have a fragipan and thick clay skins.

Most of the soils that concern us are quite old soils, presently in Pale-great groups. These are largely on stable surfaces and are rarely severely eroded. They are soils in which the clay skins could have been destroyed. Argillic horizons certainly are not now in the process of formation. Soils on the more recent surfaces, typical of the mountains of the West Indies and Venezuela, seem to have the clay skins to identify the argillic horizon if it is exposed at the surface by erosion; these do not seem to be causing problems in classification at the order level. I might add that here in Venezuela I find enough clay skins in the Paleustults, if I use a stereoscopic microscope, to identify an argillic horizon by its present definition. We can, however, make the problem of classification simpler. The soils that have all of the following properties can be placed unequivocally in Alfisols or Ultisols by definition changes of the orders.

1. A hyperthermic, isomesic, or warmer iso-temperature regime. (I am not sure if this should exclude isomesic temperatures.)

2. A subsurface horizon that has:

   a. Inactive clays (to be defined by the committee, but if this proposal is to work they must have an apparent CEC (acetate) of 16 meq/100 g clay or more).

   b. More total clay in the fine earth fraction than an overlying subhorizon that is less than 30 cm above as follows:

      (1) If the overlying horizon has less than 15 percent clay, has at least 6 percent (absolute) more clay.
      (2) If the overlying horizon has 15 percent or more clay but less than 40 percent, the ratio of clay in the fine earth fraction to the overlying horizon is 1.4 or more.
      (3) If the overlying horizon has 40 percent or more clay, has 16 percent (absolute) more clay or more.

   c. An upper boundary within 2 m of the soil surface of the overlying horizons have a sandy particle-size class, and within 75 cm of the soil surface if the overlying horizons have a loamy or clayey particle-size class.

   d. Less than 10 percent weatherable minerals in the 20 to 200 micron fraction.

If the soils that have these properties are grouped with Alfisols and Ultisols the problem of identifying translocated kaolin may disappear. This proposal is made for discussion by the committee. All limits are subject to change. You will notice that for these soils we can use the French ratio of 1.4 for lessivage in the loamy soils rather than the 1.2 ratio used in the argillic horizon definition. The latter was set to fill the Mollisols. Alfisols and Ultisols can stand a wider ratio. A limit on depth to the upper boundary seems necessary to eliminate problems with soils that have a deep lithologic discontinuity. The proposed limits provide for arenic and grossarenic subgroups, both of which we will want in Venezuela. The limit on weatherable minerals is proposed as a further safeguard against picking up a Fluventic Inceptisol or Entisol where there is a loamy horizon over a clayey one. Most of these do not have inactive clays, but alluvium from a region dominated by kaolinite soils could have inactive clays.

Some initial comments on the letter from G. Smith:

In respect to the wider argillic ratio (1.4 instead of 1.2), S. Buol and F. Beinroth are in favor of maintaining the present 1.2 ratio. After going through available data, I would agree with this and would like to see the requirements kept as in Soil Taxonomy (p. 27, sub 1). Another point is that it may be difficult in the case of low activity Alfisols to maintain that there should be less than 10 percent weatherable minerals in the 20-200 micron fraction. A good portion of these Alfisols in W. Africa on Basement Complex rocks do have more than 10 percent weatherable minerals, a characteristic that I would hope to bring out in the subgroup level (circular letter no. 1, pp. 8).

Comments on the points raised in this section are welcome, especially from those members who have experience with soils that do not show clay skins but otherwise "behave" like an Ultisol. To my knowledge the problem is only posed by Udults, and possibly Humults, so we may not need to bother with Alfisols.

D. Distinction of Alfisols-Ultisols

Among those who agreed with circular letter no. 2, point 2, first paragraph, there seems to be a fairly general agreement to add the 50 percent acetate BS as an alternative characteristic for distinguishing Alfisols from Ultisols. This would require only an addition to the definitions of Alfisols and Ultisols (resp. pp. 95 and 349 of Soil Taxonomy).

Several collaborators, among them H. Eswaran (Ghent), came up with alternate regressions between the various BS data, remarking that in the "critical" zone (40-60 percent acetate BS) the relationship is linear.

No further pertinent data were received on the relationship between the KCl BS (ECEC at soil pH) and the critical values for the $BaCl_2$ and acetate BS. Juo's second equation (circular letter no. 2, p. 13) would give about 80 percent KCl BS as the equivalent of 50 percent acetate BS. This equation was determined for the argillic horizons in a series of low activity clay soils ranging from Alfisols to Ultisols. I hope that we will receive additional data for other low-activity clay soils.

W. Sombroek, commenting extensively on methods of CEC determination, points out that considerable differences in CEC data (and, hence, in BS data) occur when the same determination is done of the same soil by different laboratories. At IITA we found a similar trend, pointing to the desirability of obtaining data on a number of critical "benchmark" soils, with analysis by several bonafide laboratories. I might ask Sombroek, whose group is following up this topic, to take the lead in providing additional data.

I now have to briefly come back on the proposal of C. Sys (circular letter no. 1, p. 7) and its alternate, to group all low activity clays in Ultisols. Two later comments, from J. Bennema and W. Sombroek, are in favor of classifying all low activity clay soils with argillic horizons as Ultisols while maintaining the present separation based on base saturation for the soils with a higher clay CEC. While in Hyderabad I discussed this specific topic, among others, with W. Johnson. Offhand I would say that such a change would meet very considerable resistance; as F. Beinroth remarked, the proposal would entail profound changes in the structure of Soil Taxonomy, while the advantages of the change are uncertain. However, as an "impartial" chairman, I would request that the persons involved (Sys, Bennema, Sombroek, and quite possibly our Brazilian member) work out a more precise proposal, showing expected changes in the keys. This could then at least be presented as a minority proposal to the USDA. For the time being, however, I will let the base saturation criterion, as amended, stand for the Alfisol-Ultisol separation as regards our further deliberations.

As was mentioned in the second letter, we will refer to the "summation method" of Soil Taxonomy as $BaCl_2$ CEC; to neutral NH_4OAc displacement as acetate CEC; and to unbuffered 1 N KCl extraction as KCl CEC. The corresponding base saturation values are indicated as $BaCl_2$ BS, acetate BS, and KCl BS.

E. Temperature requirements for low activity clay soils

The most hotly debated item in our committee is undoubtedly the question of whether or not a temperature regime limitation should be introduced in the pertinent great groups we are trying to set up (i.e., Alfisols and Ultisols with an aquic or udic moisture regime). Collateral to this the overall use of "Trop" great groups or suborders (as in Inceptisols) was discussed. Although most of these discussions on the use of "Trop" are outside the competence of the present committee, let me try to summarize the main "schools of thought."

--Against the use of the "Trop" criterion (i.e., as an iso-temperature regime, warm or warmer than isomesic) is S. Buol who, consequently, does not want any temperature regime limitations based on "iso" versus "non-iso" in the new great groups we are trying to set up. This opinion is endorsed by R. Dudal who says "in fact, the terminology "Trop" for a tropical area does not make much sense. In those regions, everything is tropical." W. Sombroek joins with this opinion.

--In favor of expanding the "Trop" criterion to ustic and xeric moisture regimes, not only for the Alfisols and Ultisols at large, but also for other orders, are A. Van Wambeke, H. Eswaran, and M. Cline. Cline remarks that while plant growth comes to a standstill in an ustic warm climate the activity of animal life in the soil does not, and he sees the omission of "Trop" in the ustic moisture regime as a stumbling block to reach a score of ecology students and teachers. The consequence of this approach for our committee would be that temperature limitations would have to be extended to ustic and possibly xeric low activity clay taxa.

--Finally the opinion to let "Trop" stand as it is while introducing temperature limitations for the aquic and udic taxa we are discussing (G. Smith and F. Beinroth). The proposal for the limitations is given in the portion of Guy

Smith's letter copied in topic C, i.e.: The low activity great groups should have "A hyperthermic, isomesic, or warmer iso-temperature regime." I am not sure if G. Smith would want to extend the temperature limitation to ustic or dryer suborders and, if so, what the consequences would be. Until further notice I will assume that low activity clay great groups of Ustalfs, Xeralfs, Ustults and Xerults in the proposal would not have temperature limitations placed on them.

As regards our subcommittee, the precise choice we have to make is between introducing temperature regime limitations in the new groups, or not. I would like to receive more comments, so that in a next letter I may try to tabulate the various rationales for the two points of view. It is crucial, however, that we get a firm opinion from the U.S. Southern Region soil classifiers. For those working in the iso-climates of the tropics both solutions are workable. I would like to suggest that F. Beinroth and S. Buol undertake to obtain opinions on this controversy from as wide a group as possible in the pertinent areas of the U.S. and Puerto Rico, and also that we obtain at an early stage an opinion from the SCS, Washington, D.C.

Your chairman, I must confess, is not enamoured with the idea of iso-temperature regime limitations (albeit, including the hyperthermic regime) on the soils we are discussing or, indeed, with the idea at large of "Trop" great groups and suborders as defined at present. My argument is similar to the one of Dudal. And, reversing the reasoning: if the "Trop" principle is deemed necessary and useful, one should be consistent and introduce such great groups also in suborders like the Aquolls, Udolls, and Uderts. Moreover, as F. Beinroth writes, the use in Soil Taxonomy of "Trop" to connote "humid and warm conditions" is not used consistently, as there are also Ustropepts; while in Paleudults and Rhodudults the "Trop" property is reflected only at the family level.

F. Nomenclature

Three nomenclature proposals were received. "Imp," mnemonic for impotence, from S. Buol. "Inert," connotative in English, French, and Spanish, from G. Smith. "Kandi," connotative of kandites, the general name for 1:1 layer lattice silicate clays, including kaolinite. This last name was suggested by P. Buurman (Indonesia) and H. Eswaran (Ghent). The latter, in the Malaysian context, would like to have an even further refinement of the CEC/100 g clay as a diagnostic characteristic, introducing limits at:

--24 meq acetate CEC or 20 meq KCl CEC for Kandic subgroups

--16 meq acetate CEC or 12 meq KCl CEC for Kandi great groups

--10 meq acetate CEC or 5 meq KCl CEC for Orthoxic subgroups

In view, mainly, of analytical problems I cannot agree with this refinement. Eswaran cites productivity differences in soils with different low-level CEC values (per 100 g clay) as an argument for the furthest subdivision. Surely, however, this argument while possibly being valid for soils of a similar particle size family does not hold if soils of, say, coarse loamy particle size families are compared with fine clayey families. Nevertheless, the "Kandi" prefix appears to me personally the most attractive of the three proposals: soothing for the ear and less "denigrating" than impotent or inert for soils which are so important to the tropics.

I am aware (of course) that my argument in favor of "kandi" is anything but scientific, and therefore submit the three prefixes gladly to the democratic process: your preferences, please.

G. Plinthite in the classification (circular letter no. 2, point 3d)

Several comments were received.

H. Eswaran agrees that plinthite does not deserve its position at the great group level, but proposes that it be expressed at the subgroup level. He proposes to add Petroplinthic and Petroferric subgroups; the former as defined by Sys as an intermediate between plinthite and its hard or laterite form.

W. Sombroek, while indicating that the presence of "indurated plinthite" should not enter the classification unless at a very low level, stresses the importance of "soft plinthite" at a higher level, especially as regards the "real groundwater laterite." From his further discussion of the subject it is clear that we have to know much more about plinthite and its dynamic behaviour in soils, before we can find a satisfactory niche.

M. Cline would agree to relegating "plinthite" soils to subgroup distinctions, with such Plinthic subgroups to be treated as "extra grades." He uses the fact that ortstein is separated only at the family level as an argument. Your chairman, even after having studied recently the real "Buchanan laterites" in India, shares this opinion.

G. Smith has no firm opinion beyond the fact that there must be a genetic difference between soils that have it and those that do not. He indicates that subgroups set up for the United States and Puerto Rico need to be retained: "Plinthic subgroups were set up because horizons that have a little plinthite were found to be restrictive to roots and to water movement, having the same effect as a fragipan."

I do hope to get further comments, e.g. from R. Isbell in Australia, where extensive studies on the subject of plinthite and its hardened forms have been made. I want to point out that the subject is, in fact, only indirectly related to the mandate of our committee, notably for finding the correct place of the low activity clay great groups in the key. If we maintain the present "Plinth" great groups, we can key the low activity taxa out before the "Plinth." In that case, a Plinthic subgroup is in order. The alternative is to key them out after the Plinth great group, which would require a "Kandic" subgroup.

W. Sombroek's experience in the Brazilian Amazon region is relevant in this respect; he found that wherever the CEC is relatively high, any so-called "plinthite" does not harden and, therefore is not plinthite according to the Soil Taxonomy definition.

H. Proposals for keying out low activity clay groups

Several proposals have been received and have been carefully noted by your chairman. However it appears premature to bring these to the table now, before we have majority opinions on some of the basic alternatives of diagnostic characteristics and nomenclature discussed as yet. Those who have made proposals may want to review them, those who did not make proposals may want to do so. If satisfactory progress is made on some of the basic points, I will try to devote most of my next letter to alternate key proposals and definitions. This, of course, requires reasonable consensus, and willingness of our committee members to adapt their own particular expertise to the more general picture.

Appendix 1 to Circular Letter No. 3
(Contribution of G. Uehara, University of Hawaii)

This is in response to your request to identify and discuss soil properties which are accessory to low activity clays. I will discuss chemical and physical properties separately.

A. Chemical

The chemical basis for separating clays on the basis of activity is the origin of surface charge. In low activity clays the surface charge arises from adsorption of potential determining ions (pdi). For soils the most important pdi's are H^+ and OH^-. In other clays the surface charge arises from defects (isomorphous substitution) in the interior of the crystal lattice, and the charge is said to be permanent. In permanent charge minerals soil management practices, whether to grow crops or for engineering uses, depend on manipulating potentials some distance from the clay surface. The management parameters are most frequently salt concentration and cation valence.

In low activity clays manipulation of salt concentration and valence not only alters potentials, but surface charge density as well. In fact in low activity clays if one holds pH constant, the change in salt concentration and ion valence is fully accommodated by changes in surface charge density. Since CEC is the product of specific surface and surface charge density, CEC is valence and concentration dependent.

$$\text{CEC(meq/g)} = \text{specific surface (cm}^2\text{/g) X surface charge density (meq/cm}^2\text{)}$$

Texture is a very useful soil property because it gives us an estimate of the specific surface, and therefore CEC and all properties accessory to CEC. The relationship between CEC and texture is very useful in permanent charge minerals, but is less than adequate in low activity clays. In low activity clays (termed constant surface potential colloids by physical chemists and, unfortunately, pH-dependent charge colloids by some soil scientists), the surface charge density varies with salt concentration, counter ion valence, pH, and even temperature. Addition of phosphate fertilizer and subsequent adsorption of phosphorus also increases surface charge. The mineralogy classes in the soil family of Soil Taxonomy give us information on soils with low activity clays. But when we use buffered 1 N NH_4OAc or even $BaCl_2$ to measure CEC we run into problems with concentration, valence, pH, and dielectric constants (alcohol). Virtually every step in conventional CEC measurements alters the very parameter we are striving to measure. Even cation retention with unbuffered NH_4Cl suffers from problems with concentration and dielectric constants.

In soils with low activity clays base saturation is meaningless because CEC does not carry the same implications as in permanent charge systems. The most useful measure of cation retention capacity for low activity clay systems is the effective cation exchange capacity (ECEC) which is the sum of Ca, Mg, K, Na, plus the KCl extractable aluminum (acidity). In non-manganiferous soils percent aluminum saturation is the best index for liming acid soils. This parameter has been widely tested in the Ultisols of the Southeastern U.S. and the tropics. A problem arises when the ECEC becomes exceedingly small as in the Acrustox and Acrorthox. But for such soils their unique place in the classification system tells us they should be treated differently.

In short, if we want to, as Dr. Smith points out, "make the greatest number and the most important statements about a soil," we will need first to determine whether the soil system is of the constant surface potential or constant surface charge type and then apply the appropriate chemical models to each system. The classification system becomes fuzzy when we apply models fitted to the constant surface charge type to soils with low activity or constant surface potential clays. In fact this is the reason for the fundamental difference in soil behavior of Alfisols of the continental U.S. and the Alfisols of equatorial West Africa.

B. Physical Properties

Skempton* defined clay activity as the ratio of plasticity index to clay content. He showed that for a given clay content, high activity clays have a high plasticity index and low activity clays have a low index. We have plotted CEC (NH_4OAc, pH 7) per 100 g clay versus plasticity index divided by clay content and obtained a highly significant correlation. Soils with low chemical activity (ECEC) are those with low plasticity indices per unit clay content. We have no way of knowing whether the correlation would improve if ECEC had been used in place of NH_4OAc CEC.

This kind of relationship merely confirms what we have known all along, namely that soils with low CEC clays possess physical properties very different from soils with high CEC clays. The Oxisols of Brazil, Hawaii, and Puerto Rico have a field capacity near 0.1 bar, have high saturated hydraulic conductivity, and hold about the same quantity of water per unit mass of clay at 15 bar pressure.

There is also a feeling (recognized by soil engineers) that interpretation of the Unified Classification systems requires adjustment when applied to soil with low activity clays.

As we move from the Oxisols to the Ultisols and Alfisols (intertropical) the clay activity generally increases. Soils are not made up purely of constant surface potential or constant surface charge minerals, but, most commonly mixtures of both. A hybrid model is needed to handle these mixed systems. M. Weaver of Cornell University is taking a stab at this problem.

In Ultisols the problem is not as serious because the high activity clays (montmorillonite and vermiculite) have been altered to low activity aluminum interlayered chlorites which begin to approach kaolinite in activity. The real problem of classifying soils into behavioral groups occurs in Alfisols (Inceptisols are equally fuzzy but we seem to be resigned to it in this order). In Alfisols we have moderately active fine-grained micas as the dominant clay mineral in the glaciated regions of the U.S., as compared to kaolinitic and

* Skempton, A. W., 1953. The Colloidal "Activity of Clays", Proc. Intern. Conf. Soil Mech. Foun. Eng., 3rd, Zurich, Switzerland, 1:57-61.

oxidic mineralogies in the intertropical zone. This difference does not bother me since I am accustomed to looking at the family level for management interpretation, and I know just enough soil science to make the necessary adjustments.

But for teaching Soil Taxonomy and assisting researchers in discovering important new relations among soils, an orderly and rational classification of soils is needed. I like G. Smith's suggestion that we designate and separate suborders into great groups with an X until we reach some kind of consensus on where we should head.

I still believe we need to meet together as a group in a workshop if we expect to achieve any kind of consensus.

December 30, 1975

Soil Property	Low Activity Clays	High Activity Clays
plasticity index	low	high
swelling potential	low	high
permeability	high	low
cation leaching	high	low
anion adsorption	high	low
phosphate fixation	high	low
crusting	low	high
shear strength	high	low
CEC	low (variable)	high (constant)
salt concentration dependent	yes	no
dielectric constant dependent	yes	no
pH-dependent	yes	no
counter-ion valence dependent	yes	no
temperature dependent	yes	no
aggregate stability	high	low
water dispersibility	minimum at or near isoelectric point	variable
irreversible drying	common	rare
chemical dispersion	difficult	easy
pH in water = pH in 1 N KCl	possible	rare or not possible
pH in water < pH in 1 N KCl	possible	not possible
pH in water > pH in 1 N KCl	very common	almost always, if not always, the case
possess isoelectric point or zero point of charge	yes	no
origin of surface charge	adsorption of pdi's	crystal defects
surface charge density	variable	constant
silica-sesquioxide ratio	low	high
degree of weathering	high	low
adsorption of heavy metals	high	low
specific adsorption of calcium	high	low
% aluminum saturation at pH 5	low	high

Note: high and low indicate relative comparisons

Circular Letter No. 4, August 1976

A. General

Recently I received news that Soil Taxonomy is now out and available for approximately $20 (U.S.). Courtesy copies have been set aside by J. E. McClelland for the (original) members of the committee and should reach us in the near future. McClelland did send, together with other comments, a computer print out of soil series in the U.S. and Puerto Rico in "tropo" great groups and Tropepts, as well as soil series in oxic subgroups. In the "tropo" taxa, there are 153 soil series, of which 33 are in oxic subgroups. There are 2 "oxic" Alfisol series and 26 "oxic" Ultisol series, all of which have an isothermic or isohyperthermic soil temperature regime. It is, however, probable that in the U.S. there are low activity clay soils in other Alfisol and Ultisol taxa for which no oxic subgroups were provided. This is indicated in letters from S. Buol and from J. D. Nichols, Principal Soil Correlator. The Soil Taxonomy Committee for changes in Soil Taxonomy for the Southern states is now looking into this matter. We will not discuss this subject further until such time as additional information on low activity Alfisols and Ultisols with a "non-tropo" temperature regime is received. Thus, the temperature requirements for low activity clay soils will tentatively stand as proposed by Guy Smith (hyperthermic, isomesic, or warmer iso-temperature regime).

B. Soil properties accessory to low and high activity clays (G. Uehara's contribution)

G. Smith's comments reinforce my own initial reactions as regards some of the soil properties accessory to low activity clays (circular letter no. 3, point B). He indicates that some of the properties listed, such as positive or zero delta pH, are common in certain Andepts and Oxisols but not in soils that have a kaolinitic mineralogy [rather than an oxidic one, Moormann]. Irreversible drying is not known in Alfisols or Ultisols, although "some soils of Hawaii, classified as Humults may show some such properties, but also may be misclassified." Crusting is, according to G. Smith, a rather general problem of Alfisols and Ultisols, occurring in soils with 2:1 layer lattice clays, as well as in soils dominantly kaolinite. My own experience in Africa is that crusting is stronger in Alfisols than in Ultisols, irrespective of clay mineralogy; similar observations were made in Sri Lanka. The higher Al saturation in Ultisols definitely appears to have something to do with enhanced surface structural stability, irrespective of whether the soil contains 2:1 lattice clay or not.

Two important statements by Smith follow: "Rhodic great groups and subgroups were established because of their differences in crusting from other related soils, not because of their differences in color ..." "Not all of the rhodic soils have oxidic mineralogy or even kaolinitic clays. No rhodic great group was provided in Humults or Oxisols because crusting did not seem to be a serious problem."

My question to G. Uehara: Taking the list of accessory characteristics of low activity clays, is it possible that you have mainly considered soils dominated by or with a considerable content of constant-potential sesquioxides?

A. Herbillon (University of Louvain, Belgium) suggests that we might have a look at the relationship between silica status and CEC. For a series of Nigerian samples it was found that there is a reasonable correlation between extractable silica and clay mineralogy. Samples from soils with smectite and a higher CEC all have more extractable silica than samples in which no smectite was detected by various clay-mineralogical analyses. Experimentally it was shown that desilification of low CEC samples changed the soil in the sense of Goro's list of characteristics of low activity clays (lower CEC, lower permanent charge, lower delta pH, better crystallinity of Fe oxides, lower dispersion rate). It seems worthwhile to test the silica-status parameter for its usefulness as an accessory characteristic to distinguish between high and low activity clays. Herbillon is requested to inform me of the pertinent analytical method so that I may distribute it to the committee members.

Comments of R. Isbell and J. Bennema touch upon G. Uehara's letter and list, but in a somewhat different context; this will be dealt with below. I would, at this stage, like to leave the subject open for further discussion. What we need is more knowledge of accessory properties of low activity clays, especially such properties that would help us to define and better describe the taxa which are within the competence of our committee.

C. The argillic horizon

This subject continues to be discussed in a fair portion of the correspondence. As a general topic it exceeds in several points the terms of reference of our committee.

--Isbell reviewed in his letters and in a draft publication his objections and those of most Australian pedologists to the present concept and definition of the argillic horizon. A principal objection is that in many cases the proportion of translocated clay, either identified by clay skins or by the ratio of fine clay to total clay, is small so that the genetic implications present in the definition "seem to rest on rather flimsy grounds." A definition of an argillic horizon as merely that based on certain particle size specifications is felt to be safer, and in that respect the Australians would prefer the wider ratio proposed by Smith.

Isbell points to the problems of soils that are presently in doubt as to whether they are Ultisols or Oxisols, a problem that seems to occur in many fine-textured kaolin-sesquioxide soils of the tropics (including North Queensland). He would prefer that the preliminary definition of the oxic horizon be permitted to be substantially similar to that of the argillic horizon, and concludes "the main feature we surely want to emphasize in Oxisols is their chemistry and mineralogy, i.e., they are extremely weathered soils consisting essentially of kaolin and sesquioxides with little or no ability to retain cations."

The overall contention of Isbell's letters, and publications, and of the Australian point of view as regards the merits or demerits of the argillic horizon, exceeds our terms of reference, but a number of points are clearly related to our work. From the Australian work it appears again that the main difficulties arise in Ultisols of the udic to perudic warm climates, and more particularly in the Kandiudults and Kandihumults. This same point is raised in letters I received from H. Eswaran and S. Paramananthan (Param, for short) in

Malaysia, and from A. Herbillon, who comments on the Sarawak conditions. No serious difficulties as regards recognition of an argillic horizon are reported for "Kandi" great groups with an ustic soil moisture regime. Mostly the argillic horizons in Kandiustalfs and Kandiustults of my knowledge are well developed and easily recognizable by the textural profile, clay skins, or both. I have no experience with Kandiudalfs, the existence of which is doubtful. In the low activity Aqualf suborder difficulties in the recognition of an argillic horizon have not been reported. My own experience is that the argillic horizon becomes more pronounced in the hydromorphic members of relevant toposequences. However, difficulties are reported by H. Eswaran with Tropaquults, which would comprise our Kandiaquults.

In this context I wish to quote from G. Smith's letter: "I am not surprised that clay skins are scarce or absent in the wetter udic and perudic soils. This has been my observation in the U.S. and in Europe. Consequently, I have considered these soils to have cambic horizons. In the discussion of the argillic horizon I emphasized the correlation between the presence of the argillic horizon and a seasonal moisture deficit. Perhaps people are trying too hard to find argillic horizons."

Let me now review remarks on G. Smith's specific proposals in circular letter no. 3, pp. 19-21.

1. Various writers wonder why "inactive clays" (G. Smith's definition 2a) should have an apparent CEC/acetate of 16 meq/100 g clay or <u>more</u>. Should this be "or <u>less</u>," or should it be 24 meq/100 g clay acetate or <u>less</u>?

2. In Malaysia (Peninsular) where thin sections have been made of all benchmark-pedons, the separation of Ultisols-Oxisols is based on the presence and absence of clay skins. A real problem arises in soils without any dry season which have a horizon 30-50 cm thick which has all the properties of an oxic horizon and which overlies a "good, thick argillic horizon." Accessory properties, including the "textural profile," are those of Ultisols, and in terms of management such soils are very similar to Udults, though they would have to be classified as Haplorthox when following the key.

3. H. Eswaran is afraid that, as Smith's definition now stands, there would be many Haplorthox and Acrorthox in Malaysia which will meet these requirements even though not showing any evidence of translocated clay at greater depth (4 m). He proposes a rider in Smith's definition (2c), as follows: An upper boundary ... loamy or clayey particle size class, and have some clay skins on peds and in pores below the upper boundary [no depth requirement given, Moormann].

4. Herbillon, reporting on soils in Sarawak, indicates that 12 series can be grouped with Ultisols according to Smith's definition, using the parameters for a subsurface horizon with a higher clay content as specified. The requirement that the increase be within 30 cm would fit most Sarawak soils. Here again there is a difficulty with soils that have an apparent oxic horizon but that still show the increase in clay with depth sufficiently to qualify as Alfisols. Trouble arises in certain cases where the clay increase is insufficient due to truncation or otherwise. In Sarawak, all these Ultisol-Oxisol transitions appear to occur on quite young land surfaces, where weathering is extreme.

5. The discussions in respect to the argillic horizon, as related to Alfisols and Ultisols with low activity clays may tentatively be summarized as follows:

   a. Where an argillic horizon is easily recognizable in a position diagnostic for the taxa with which we are dealing, Soil Taxonomy can and should be followed as it now stands. This implies that the Smith's proposals are to be considered as a special provision for borderline cases, to be defined below. This also implies that our committee, in the continuation of its activities should not be the forum for discussions on the merits or demerits of the argillic horizon as a diagnostic characteristic. Basically, the definition and description, given in Soil Taxonomy, pp. 19-27, is to remain our guideline, although we should point out weaknesses where they occur.

b. While difficulties in diagnosing the argillic horizon may be encountered in most or all of the taxa we are discussing, the majority of such difficulties appear to arise in the Ultisol-Oxisol transitional pedons of the humid to perhumid moisture regimes. These difficulties are of various nature:

--soils, that have the textural profile requirements of an argillic horizon, have subsidiary characteristics of Ultisols, lack the general and specific characteristics of Oxisols, but do not show any translocated clay (cutans) in thin sections, unless deeper in the pedon. For this kind of soils, the Smith's proposals would work.

--soils, that have the textural profile requirements of an argillic horizon, have, at some depth cutans which are both visible in the field and in thin sections, but that do have a subsurface horizon above the argillic horizon which has all the characteristics of an oxic horizon (Soil Taxonomy, pp. 36-41). Classifying such soils as Oxisols, when the oxic horizon is only slightly thicker than 30 cm is unsatisfactory for several collaborators of the committee, especially those from equatorial S.E. Asia, both on management properties grounds (such soils "act" as Ultisols) and because of the fact that such "Oxisols" mostly occur on younger, geomorphologically unstable surfaces.

In order to classify this kind of soils, which are generally felt to belong with Ultisols, more further-reaching revisions in Soil Taxonomy may be required, e.g. admitting an oxic horizon of, say, 50 cm or less in Ultisols (Soil Taxonomy, Ultisol definition, p. 349, item 3; also p. 350, item 6) or exclude from Oxisols such soils that have an argillic horizon below the (thin) oxic horizon at a depth to be defined, but which would most probably have to be something like 125 cm or less. The Smith's proposals, with the amendment by Hari Eswaran may work for these soils on condition that soils with a "minor" (to be defined) oxic horizon are admitted to Ultisols. This would be the opposite of the preference of the Australians, who, as R. Isbell writes, prefer Oxisols where an argillic horizon is admitted, as it was in previous approximations of Soil Taxonomy.

c. As far as I can see it now, the Smith's proposals would be relevant for Kandiaquults, Kandiudults, and Kandihumults; the latter probably mainly in the udic or perudic soil moisture regime range. This would imply a definition change of Ultisols (but not of Alfisols), to be reflected on p. 349, item 1. Smith's proposal would, probably in a simplified form, have to be added as point 1c in the definition of Ultisols, so as to admit our problem soils into Ultisols. I have tried to do this, but as yet without much success. I would like to solicit your proposals for this definition change.

In the meantime, we should keep this subject open for further discussions in view of the fact that these soils, transitional to Oxisols are geographically widespread in several equatorial areas.

D. CEC and base saturation

G. Smith points to Soil Survey Investigations Report No. 12 as the only publication known to him which relates considerable numbers of acetate CEC to KCl CEC (circular letter no. 2, pp. 12-13). From these data, he finds an approximate relation of 16 meq acetate CEC = 9 meq KCl CEC, and 24 meq acetate CEC = 15 meq KCl CEC. Taking a soil with 24 meq acetate CEC and 50 percent acetate BS, one can calculate that the (probable) KCl BS would be 80 percent, which is indeed a good fit with Juo's second regression equation (circular letter no. 2, p. 13). Smith further indicates that: "in base-rich soils with a high pH, the KCl CEC includes some pH dependent CEC. In the Eutrorthox, which are kaolinitic, the ratio between acetate CEC and KCl CEC approaches unity. The same phenomena could occur in Alfisols, particularly Paleustalfs." [This seems, indeed to be the case for certain highly saturated oxic Paleustalfs in W. Africa, Moormann]

For your information: from data which I received from various sources, covering 24 low activity clay samples of argillic horizons for which three kinds of CEC values are known, I calculated that the average acetate CEC was 19.5 and the average KCl CEC was 13.5, which is well in line with the ratio given by Smith (i.e. 24/16.6 versus his 24/15 ratio).

From J. Bennema's letter: "For Brazilian soils a base saturation of less than 34 percent (Ca acetate pH 7) was used as a differentiating criterion." This is, for the soils studied, comparable to <23 percent $BaCl_2$ BS or >50 percent saturation with exchange acidity of the effective exchange acidity, i.e.:

$$\frac{Al^{3+}}{Al^{3+} + Mg^{2+} + Ca^{2+} + Na^{+} + K^{+}} => 0.5$$

"Under the prevailing conditions, this criterion gives a reasonable separation between more and less fertile soils."

The Al^{3+} saturation is considered a very important aspect of fertility, however, a ratio lower than 0.5 is not believed to have much influence on the fertility. Bennema suggests that Al saturation of the effective exchange complex (KCl CEC) may be a better measure than base saturation and would like discussion on this point. From the data provided by Bennema and from some other data I received on Brazilian soils, it appears that the CEC by Ca acetate at pH 7 is comparable to the acetate CEC, at least at or close to various diagnostic values.

G. Gillman from Australia suggests that to determine CEC the approach proposed by van Ray and Peech be tried, i.e., equilibrate the soil with a dilute divalent cation solution and measure the cations absorbed without removing the excess salt. Comments?

J. McClelland writes that, as a rule of thumb, 35 percent $BaCl_2$ BS is equated with 50 percent Acetate BS and that, at least at the critical point, the relationship appears to be reasonable where data by both procedures are available.

From these letters and other comments we tentatively conclude:

1. For the definition of low activity clay Alfisols and Ultisols, the diagnostic value of 24 meq/100 g clay (Acetate CEC) can be maintained.

In practice, this value will be comparable with 16 $\pm$ 1.5 meq/100 g clay (KCl CEC).

2. Within the "Kandic" taxa, a lower diagnostic value of 16 meq/100 g clay (Acetate CEC) or 9 $\pm$ 1 meq/100 g clay (KCl CEC) might, if required, be used for subgroup distinction.

3. A 35 percent $BaCl_2$ BS is taken to correlate with a 50 percent Acetate BS ($\pm$ 4%) and with a 75 percent KCl BS ($\pm$ 5%) for practical classification purposes.

4. Members of the committee point out that further correlations of critical BS and CEC values, as determined by other methods, would be useful in order to interpret data from additional national soil surveys. Also, other values such as Al saturation should be tested as to their usefulness for classification.

With this, I intend to let the subject rest, unless further factual data on the above are received.

E. Alfisol-Ultisol distinction

First, a comment of J. McClelland:

"We would be reluctant to change the distinction between Alfisols and Ultisols on the basis of base saturation. But the relationship between percentage base saturation in soils with very low CEC should be evaluated because a small error in determining CEC becomes critical."

Although accepting the alternate 50 percent acetate BS, especially since this determination is more commonly used, further comments of committee members and others associated with our work tend to leave the BS criterion as the (main) differentiating characteristic between Alfisols and Ultisols. The addition of 75 percent KCl BS as a second alternate remains to be tested in more low activity clay Alfisols and Ultisols.

J. Bennema, following my comments on the "Sys approach" in the third circular letter (p. 23), writes:

"The incorporation of the low activity clay taxa with higher base saturation (into Ultisols) need not upset the Soil Taxonomy system. The only difference could be that the newly defined great groups with low activity clay and higher base saturation have to be placed in the Ultisols instead of in the Alfisols. The subdivision of these groups could be the same. The new groups could be: Eutraquults, Eutrudults, Eutrustults, Eutroxerults (if needed), Eutrohumults (if needed); the simplest solution is to regard the plinthic great groups of the present classification on the subgroup level, e.g. Plinthic Eutraquults."

J. Bennema requests further comments. My own comment at present would be that in the work of the subcommittee we will continue to use the proposal of circular letter no. 2. This proposal seems to have the agreement of most, and it would mean the least change in Soil Taxonomy as it now stands.

F. Nomenclature--great groups required

The use of Kandi for the great groups we are dealing with is generally accepted; as you have noticed, I have been using it in the previous paragraphs. Some have used Kand without the i, but, unless overruled, I will leave the i in.

G. Smith makes the provision that we should agree that we are discussing soils whose clay fraction is dominantly kaolinite, dickite, nacrite, and tabular halloysite, and asks how we should treat tubular halloysite. I can agree with this provision as regards the soils in West Africa for which I have data available. Tubular halloysite seems mainly related to freshly weathered crystalline rocks, and, though possibly present in some horizons diagnostic for "Kandi" great groups, it does not seem likely that its presence will require classification changes.

Kandi great groups of Alfisols would have the following diagnostic characteristic in common: a CEC that is less than 24 meq/100 g clay (by NH_4OAc) and have a cation retention that is less than 12 meq/100 g clay in the upper 50 cm of the argillic horizon or below a mollic or umbric epipedon if part of such an epipedon is also part of the argillic horizon.

Kandi great groups of Ultisols would have the following diagnostic characteristic in common: a CEC that is less than 24 meq/100 g clay (by NH_4OAc) and a cation retention that is less than 12 meq/100 g clay in:

1. the upper 50 cm of the argillic horizon or below an umbric epipedon if part of such an epipedon is also part of the argillic horizon, or

2. a subsurface horizon below the epipedon that has more total clay in the fine earth fraction than an overlying subhorizon that is less than 30 cm above as follows:

   a. if the overlying horizon has less than 15 percent clay, has at least 6 percent (absolute) more clay; or

   b. if the overlying horizon has from 15-40 percent clay, the ratio of clay in the fine earth fraction to the overlying is 1.4 or more; or

   c. if the overlying horizon has 40 percent or more clay, has at least 16 percent (absolute) more clay.

Note: The above definition of the diagnostic subsurface horizon follows Smith's proposal of the circular letter no. 3, pp. 19-21.

The following great groups would be required:

--in ALFISOLS: Kandiaqualfs (Possibly redundant; I have never seen one, but someone else may have); Kandiustalfs (widespread, e.g. in West Africa); Kandiudalfs (only rare specimen known to me in West Africa). No "Oxic" subgroups are mentioned in Xeralfs in Soil Taxonomy, nor has a provision been made for restricting the Typic subgroup in Xeralf great groups on the basis of a CEC of more than 25 meq/100 g clay in the argillic horizon. The question is then do we need Kandixeralfs or can we forego this great group, either because it does not occur, or because low CEC in this case would be of lesser importance and could be taken care of at the subgroup level. More information is needed in this respect.

--in ULTISOLS: Kandiaquults (regionally important, e.g. on older river terraces of S.E. Asia); Kandihumults (regionally important, especially in areas with parent materials derived from basic crystalline rocks); Kandiudults (a most important great group in the humid tropics); Kandiustults (much less common, but occurring on many older surfaces, possibly related to previous more humid climatic cycles). No "Oxic" Xerults are mentioned in Soil Taxonomy. Personally, I do not know of any Kandixerults, and we may provisionally leave them out if this is in agreement with your opinion and with your experience.

G. Plinthite in the classification

I should point out again that our discussions on this subject pertain primarily to the relevant place of the Kandi great groups in a Soil Taxonomy revision (see circular letter no. 2, p. 16). Further reactions in respect to Plinthite were received:

--R. Isbell discussed the matter with his colleagues. They would want an improvement of the definition of plinthite, as well as provisions for some kind of "petroferric horizon" to cater for the range of ferruginous materials in the soil that are already hard in unexposed situations. In general the Australian colleagues would like to use both plinthite and a "petroferric" horizon at the same hierarchical level of the subgroup, while pointing out that in many Australian soils "laterite" is a soil parent material rather than a soil horizon material.

--J. Bennema indicates that the present Plinth great groups occur only in kaolinitic clays [not always true, Moormann]. He points to two alternatives, i.e.:

--key out Plinth great groups before Kandi great groups, and to consider the low activity subgroups of the Plinth great group as Typic; or

--delete the Plinth great group and make Plinthic subgroups, whereby two kinds would be needed, i.e., one for the present definition of Plinth great groups and another for the present definition of Plinthic subgroups.

--Bennema thinks that the hardened plinthite in Alfisols, Ultisols, and Oxisols should be handled at the lower levels of the classification [family??].

--S. Buol comments on various forms of plinthite and the "petroferric" horizon, as well as their position in the profile. The Plinth great groups only rarely occur in the U.S. and Puerto Rico.

--J. McClelland indicates that there are four Plinth great groups in Soil Taxonomy, all with an aquic or peraquic moisture regime and with more or less continuous plinthite. Presumably, like fragipans or duripans, continuous plinthite restricts water movement and root penetration, and it should be dealt with in an analogous fashion in Soil Taxonomy. Hence, it is McClelland's opinion that "Plinth" great groups should be maintained as well as "Plinthic" subgroups where the plinthite is less restrictive. A comment: my experience with plinthite is that it does not, to a considerable extent, inhibit root penetration. From this point of view, it could well be treated at the lower level of the subgroup. The present Plinthic subgroups could, in this opinion, be relegated to the lowest levels of the classification.

--The Malaysian comments are in favor of using plinthite at the subgroup level and of a better definition of plinthite.

You may see that, as it now stands, it is difficult for our committee to make a firm proposal. However, the majority's opinion of those who have considerable experience with plinthite is in summary:

1. Downgrade its occurrence in Kandi great groups to the subgroups level, which would imply considering the present "Plinthic" subgroups either as a separate paraplinthic subgroup or as a diagnostic characteristic at a lower level.

2. Key the Kandi great groups out before the Plinth great groups, whether or not Plinth great groups would be maintained.

I would like to proceed on with our activities in accordance with these majority opinions, while keeping the subject open for discussion within the context of our mandate.

A. Low activity clay Alfisols and Ultisols in Brazil

Just after finishing circular letter no. 4 I received an important communication from M. H. Camargo giving the Brazilian point of view on various topics discussed in circular letter nos. 1-3. A summary of his remarks follows:

--The adoption of the 50 percent acetate BS for an alternate limit between Ultisols and Alfisols is satisfactory and meaningful for Brazil; this limit has been used since 1970 to distinguish "eutric" and "dystric" soils.

--Brazilian low activity Alfisols and Ultisols are mostly, not to say always, "kaolinitic" and not "sesquioxidic."

--Many of the soils identified as Ultisols and Alfisols do not show visible clay skins, particularly when udic and perudic. The increase in clay content (clay B/A ratio) has been considered diagnostic for (the presence of an) argillic horizon.

--"A second maximum of water dispersible clay, as well as of organic matter, when present in soils lacking visible clay skins ... can be interpreted as a manifestation of colloidal movement .... This holds true in the case of sandy and coarse loamy argillic horizons, and for some "fragic" argillic horizons."

--Extensive comments are given on the grouping together of low activity clay soils with an argillic horizon (circular letters no. 1, pp. 5-6, and 4, pp. 33-35). While I understand that in the early national classification of Brazil precedent was given to clay activity over base saturation, this opinion is not maintained as regards the present-day Brazilian view on the use of, and the correlation with, Soil Taxonomy. Pertinent quotes from M. Camargo's correspondence:

"The alternative of joining the low activity Alfisols to the Ultisols seems to us not convenient, for it would eliminate from Alfisols problems being added to Ultisols which would comprise present Ultisols that already include low and high clay activity .... The implication is that aggregating the present low activity Alfisols to the Ultisols will effect a more heterogeneous grouping encompassed by the Ultisol order, besides reflecting a certain inconsistence in criteria applied to Ultisols compared to Alfisols .... We have been adopting differentiating first on basis of base saturation (critical value 50 percent acetate BS), followed by differentiation according to clay activity expressed by CEC (acetate) < versus > 24 meq/100 g clay, discounting for carbon in the same fashion [as] adopted in Soil Taxonomy."

My footnote to these particular comments: the Brazilian diagnostic criteria separating high and low base saturation, and high and low clay activity soils with an argillic horizon, appear completely compatible with those used in Soil Taxonomy. Taxa distinguished and named in the national scheme can therefore be translated easily into taxa of Soil Taxonomy, or, in effect, such Soil Taxonomy taxa can be introduced into the Brazilian system without much reshuffling of existing data. Since this is so for Brazil, and, since by now most countries where low activity clay Alfisols and Ultisols occur have accepted the Alfisol-Ultisol distinction as set out in Soil Taxonomy, we will, as far as our committee is concerned, refrain from making alternative proposals.

--M. Camargo has objections to "Tropo," similar to those discussed in circular letters nos. 2 and 3. If a temperature limitation has to be adopted for the "Kandi" great groups, he would prefer it to include the thermic temperature regime.

B. Contribution of H. Eswaran, Ghent

A very useful contribution was received from Eswaran; the first three items of his letter are given in appendix 1 for your information and comments. The fourth item in Hari's letter is a proposed key for Udults, which will be discussed below.

As regards item A of Eswaran's letter (charge characteristics and base saturation), I do not believe that the terminology used in previous circular letters was particularly confusing; although it is true that as a non-chemist I have had quite a bit of trouble with various synonyms used in publications. The list, however, appears useful and terms may be quoted accordingly in further correspondence of the committee.

As regards item B.3. of Eswaran's letter, I wish to point out that the main basis of our exercise is to upgrade the "oxic" Alfisols and Ultisols. These Oxic (Orthoxic, Ustoxic, etc.) subgroups have been defined in Soil Taxonomy as differing from Typic subgroups by not meeting the following requirement: "have more than 24 meq CEC per 100 g clay (by NH_4OAc) and have a cation retention capacity from unbuffered 1N NH_4Cl of more than 12 meq per 100 g clay in the major part of the argillic horizon." If we are to use an acetate CEC critical value of 16 meq for Kandi great groups, there undoubtedly will be an uproar and much confusion as what to do with the soils which have between 16 and 24 meq, which includes a considerable number of established U.S. series. What might be considered is to introduce a 16 meq acetate CEC limit for a subgroup distinction within Kandi great groups, but we surely will require much more firm data and further discussions before taking any action on this. (I refer also to circular letter no. 3, pp. 25-26 and no. 4, pp. 35-36). Questions in this respect are:

--is such a subdivision really needed and meaningful in terms of soil genesis and/or management;

--if so, should the typic Kandi great groups have an acetate CEC between 16-24 meq, and the non-typic subgroup less than 16 meq; and

--can such a subdivision be readily used in soil mapping and will it result in more meaningful soil maps (unknown, even in Malaysia where soil series belonging to Kandiudults have not been based on this particular criterion).

Regarding item C of the Eswaran letter: plinthite, petroplinthite, and petroferric contact--I think that this is an excellent outline, one which we can use to define subgroups in our Kandi great groups. It is not, however, without its own peculiar difficulties in the field. For instance, what to do about soils that have petroplinthite overlying plinthite within 125 cm from the surface, a fairly common occurrence in Plinth great groups. Or worse, what do we do when there is a petroferric contact, overlying petroplinthite, and plinthite all within the same diagnostic depth. Such profiles, though rare, may be occasionally met.

C. Keying out the great groups of UDULTS

Complete proposals for a key to Udults were submitted separately by S. Paramananthan and H. Eswaran, both serving as examples for keys to other relevant suborders. I have combined these two proposals, adding elements from other correspondence (e.g. from S. Buol) and from my own experience. In the draft key which follows below the letters within brackets refer to the comments, listed after the key.

Assumptions made while working out this key were:

1. that 50 percent acetate BS is accepted as an equivalent diagnostic limit to 35 percent $BaCl_2$ BS for the distinction between Alfisols and Ultisols;

2. that pedons in which the textural profile requirements of an argillic horizon are met with, but that do not show translocated clay (cutans) in thin sections, unless deeper in the profile, be admitted to Ultisols according to G. Smith's proposal, circular letter no. 3, pp. 19-21. No corresponding change in the text of Soil Taxonomy is proposed here, but it appears that on p. 349 a point 1c is to be introduced in the definition, reflecting this assumption;

3. that no change is made as regards "Plinth" great groups as defined at present; and

4. that in the key to suborders of Ultisols, pp. 350-351, an addition be made as follows: "FC. other Ultisols that have a udic or perudic moisture regime. Udults, p. 559."

Key to Great Groups of Udults

FCA--Udults that have a fragipan in or below the argillic horizon

[a] ... Fragiudults

FCB--Other Udults that have plinthite that forms a continuous phase or constitutes more than half the volume in some horizon within the upper 1.25 m of the soil

[b] ... Plinthudults

FCC--Other Udults that have

[c] 1. a hyperthermic, isomesic, or warmer iso-temperature regime

[d] 2. a CEC of less than 24 meq per 100 g clay (by NH_4OAc) and have cation retention from NH_4Cl of less than 12 meq per 100 g clay in:

[e] a. the upper 50 cm of an argillic horizon, or to a lithic, paralithic, or petroferric contact, whichever is shallower; or

[f] b. the upper 50 cm of a subsurface horizon which
(1) has at least 6 percent more clay than the overlying horizon if this horizon has less than 15 percent clay
(2) has a clay ratio of 1.4 to the overlying horizon, if this horizon has between 15 and 40 percent clay
(3) has at least 16 percent more clay than the overlying horizon, if this horizon has more than 40 percent clay.

[g] ... Kandiudults

FCD--Other Udults that have an argillic horizon that has less than 10 percent weatherable minerals in the 20 to 200 micron fraction in the upper 50 cm and have a clay distribution such that the percentage of clay does not decrease from its maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum has skeletans on ped faces or has 5 percent or more plinthite by volume.

... Paleudults

FCE--Other Udults that have:

1. an epipedon that has a color value, moist, of less than 4 in all parts; and

2. an argillic horizon that has a color value, dry, of less than 5 and not more than 1 unit higher than the moist value.

... Rhodudults

FCF--Other Udults that have an isomesic or warmer iso-temperature regime.
[h] ... Tropudults

FCH--Other Udults ... Hapludults

Comments on the draft key of Udults

[a] No provision is made, in Soil Taxonomy, p. 361, for a Fragiudult subgroup with a clay fraction of low activity. Is such an "Oxic" or "Kandic" subgroup needed?

[b] This great group was classified by Buol and Eswaran in front of, and by Param after, the Kandiudults. If maintained in its present position an "Oxic" or "Kandic" subgroup is needed, unless such a low activity clay subgroup becomes the "Typic," in which case a subgroup name for the higher CEC variant should be found. Other subgroups of Plinthudults that I have met are Aquic and Petroplinthic, plus a combination of those two (e.g. in parts of the wet zone of Sri Lanka). Further data on possible subgroups are needed if the great group is to be maintained in its present place.

[c] The temperature limitation has been introduced in this proposal, but could be dropped if so required.

[d] The present diagnostic level of the Oxic (and related) subgroups of Alfisols and Ultisols is maintained, for reasons discussed in this and previous circular letters.

[e] The upper 50 cm of an argillic horizon are taken as diagnostic as discussed in circular letter no. 2, p. 14. Provision should be made for shallow profiles.

[f] This is, basically, the textural profile provision of G. Smith. It makes the definition of Kandiudults rather ponderous, but I see no way to simplify it.

[g] This is the place for Kandiudults, as proposed by Param and favoured by myself. H. Eswaran proposes a lower key position, after Paleudults and Rhodudults; while in an earlier proposal of S. Buol, the position would be after Paleudults, with the provision that Fragiudults, Plinthudults, and Paleudults would have "Kandic" subgroups.

[h] Query: should, for the sake of consistency, the hyperthermic regime be added to this definition?

D. Kandiudults

In proposing the Typic subgroup the important assumption has been made that this subgroup has a "Pale" textural profile. The great majority of Kandiudults are indeed deep profiles. The term "argillic" horizon in this key is used so as to include the finer textured subsurface horizon discussed previously.

Provision has been made to introduce "Petroplinthic" and "Petroferric" subgroups on a tentative basis. In the listing of subgroups the present subgroups of Paleudults have been taken as a model. However, the "combination" subgroups, such as "Arenic Plinthaquic," and others, have not been listed. We do not know which subgroups of this kind are needed as yet, and, moreoever, they can be introduced without changing the definition of the Typic subgroup.

Kandiudults

These are the more or less freely drained Udults, found in intertropical areas on a wide variety of parent materials.

They have a thick argillic horizon on all but the youngest landsurfaces. On older and more stable landsurfaces the solum is most commonly many meters thick, regardless of the particle size class of the parent material. On younger landsurfaces, subject to erosion and rejuvenation, the solum is less thick, but even here the argillic horizon usually extends below 1.5 to 2 m. A small amount of plinthite is commonly found at some depth.

Clay skins are frequently not present in the upper part of the argillic horizon and are best preserved below a depth of 2 m, where biological activity is low. Weatherable minerals are low or virtually absent unless the solum is relatively thin. Activity of clay is low by definition and in many is within the range of Odisols.

The Kandiudults are dominant soils in udic to perudic intertropical areas on all but the younger (late Pleistocene, Holocene) landsurfaces on basic rocks.

<u>Definition</u>

Kandiudults are Udults that:

1. Have all of the following characteristics:
   a. an argillic horizon that, in the upper 50 cm has less than 10 percent weatherable minerals in the 20 to 200 fraction, and has a CEC of less than 24 meq/100 g clay (by NH_4OAc) and a cation retention from NH_4Cl that is less than 12 meq/100 g clay; and
   b. a hyperthermic, isomesic or warmer iso-soil temperature regime; and

2. do not have a fragipan; and

3. do not have plinthite that forms a continuous phase or constitutes more than half the matrix in any sub horizon within 1.25 m of the surface.

<u>Note</u>: Pedon 21 of <u>Soil Taxonomy</u> would be a Kandiudult but for the temperature regime, which is mesic.

Distinction between Typic Kandiudults and other subgroups

Typic Kandiudults are the Kandiudults that:

a. do not have the following combination of characteristics in the upper 75 cm of the soil if the chroma throughout the upper 75 cm is not controlled by the uncoated sand grains; or if the chroma throughout the upper 75 cm is controlled by uncoated sand grains, do not have the following combination of characteristics throughout the upper 12.5 cm of the argillic horizon:

   1. mottles that have a color value, moist, of 4 or more; and chroma, moist, of 2 or less; and mottles of higher chroma that are due to segregation of iron; and
   2. saturation with water in the mottled zone at some time of the year or artificial drainage; and

b. have a clay distribution such that the percentage of clay does not decrease from its maximum amount by more than 20 percent of that maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum has skeletans on ped faces; and

c. do not have an epipedon as thick as 50 cm if the particle size class is sandy throughout; and

d. do not have a lithic contact within 50 cm of the surface of the mineral soil; and

e. do not have a subhorizon within 1.5 m of the soil surface that has more than 5 percent plinthite; and

f. do not have a petroferric contact within 125 cm of the soil surface; and

g. do not have petroplinthite that constitutes more than half the volume and forms a layer of more than 25 cm within 1.25 m of the soil surface; and

h. have an argillic horizon that has a color value, moist, of 4 or more, or that has mottles of high chroma in some sub horizon within 1 m of the top of argillic horizon; or have a color value, dry, more than 1 unit higher than the value, moist, in some part of the soil within that depth; and

i. have texture finer than loamy fine sand in some part of the argillic horizon and do not have lamellae in at least the upper 1 m of the argillic horizon; and

j. do not have a horizon that is above the argillic horizon whose lower boundary is deeper than 18 cm and that meets all the requirements for a spodic horizon except the horizon is intermittent; and

k. do not have a subhorizon in the argillic horizon and within 1.25 m of the soil surface that has all the properties of a fragipan except that it is brittle in 40 to 60 percent of the volume.

Note: This set of characteristics is valid for most subgroups which have come up in our correspondence. It is not valid for a special subgroup of very low clay activity (less than 16 meq) Kandiudults, proposed by H. Eswaran, or for Kandiudults with more than 10 percent weatherable minerals in the upper 50 cm of the argillic horizon, as proposed by Param. For the former, more discussion is needed; as regards the latter, this "Eutric" Kandiudult appears redundant, although Eutric subgroups will undoubtedly come up in other "Kandi" great groups.

"Non-composite" subgroups, following the above, would be:

Aquic --like Typic Kandiudults, except for a.

Arenic --like Typic Kandiudults, except for c, with or without b, and they have a sandy epipedon that is 50 cm to 1 m thick.

Fragic --like Typic Kandiudults, except for k, with or without b, e, f, or g.

Grossarenic --like Typic Kandiudults, except for c, with or without a or b, and they have a sandy epipedon that is between 1 and 2 m thick in half or more of each pedon.

Leptic --like Typic Kandiudults, except for b.

Lithic --like Typic Kandiudults, except for b and d.

Plinthic --like Typic Kandiudults, except for e.

Petroferric --like Typic Kandiudults, except for f, with or without e or g, or both.

Petroplinthic--like Typic Kandiudults, except for g, with or without e.

Psammentic --like Typic Kandiudults, except for i.

Rhodic --like Typic Kandiudults, except for h.

Spodic --like Typic Kandiudults, except for j, with or without a or e, or both.

Other subgroups can be obtained by combination of properties.

Final note: I am sure that this draft needs a lot of further work. It is mainly meant as a guide for treating the classification of Kandiudults and, by implication, as a model for treating further Kandi great groups.

Appendix 1 to Circular Letter No. 5
(Contribution of H. Eswaran)

A. Charge characteristics and base saturation

Several terms are being used synonymously in your circular letters and in publications, and I think it is necessary to adopt some conventions. I include some which I employ and which may be useful.

1. Exchangeable acidity

   This is determined with 1N KCl (Yuan 1959). The two components that are determined are hydrogen and aluminum. Whether these are truly exchangeable will be debated, but for taxonomic purposes they may be assumed to be so.

   Exchangeable Al is zero at pH KCl of more than 5.2. Exchangeable H is zero at pH water of more than 8.2. Exchangeable acidity is the sum of the two.

2. Extractable acidity

   This is determined at pH 8.2 with $BaCl_2$-triethanolamine. It is almost completely due to dissociation of active groups, and so is a measure of the pH-dependent charge.

3. Effective Cation Exchange Capacity (ECEC)

   ECEC is the sum of exchangeable bases (NH_4OAc at pH 7) and exchange acidity, and is expressed on 100 g clay.

4. Permanent Charge (PC)

   PC is the sum of the exchangeable bases and exchangeable Al, and is expressed on clay.

5. CEC at pH of the soil (ACEC)

   ACEC is determined with 1N unbuffered NH_4Cl and is expressed on clay. The values approach ECEC.

6. CEC NH_4OAc (CEC7)

   CEC7 is determined with 1N NH_4OAc buffered to pH 7 and is expressed on soil or clay.

7. CEC by sum of cations (SCEC)

   SCEC is determined by adding the bases (NH_4OAc extract) and extractable H and is expressed on soil or clay.

8. pH-dependent charge (PDC)

   PDC is the difference between SCEC and PC and is expressed on clay.

9. Charge ratio

   Is the ratio of PDC to PC.

10. Al saturation

    Is calculated on ECEC or PC.

$$\text{Al saturation}_{\text{ECEC or PC}} = \frac{\text{Exchangeable Al}}{\text{ECEC or PC}} \times 100$$

11. Base saturation

    This is calculated on any of the charge characteristics listed, from 3. to 7. Subscripts are used to indicate the type of base saturation.

    e.g. $BS_{(PC)}$ is base saturation on PC,

    $BS_{(7)}$ is base saturation on CEC with NH_4OAc.

The ECEC, PC, and ACEC estimates are not valid for soils with pH water of more than 7. The first two are also not valid for soils with excessive amounts of exchangeable Mg.

<u>Some interrelationships for Malaysian soils</u>

--When BS_7 is 50%, then BS_{Sum} is 35% and BS_{PC} is 100%.

--CEC7, 24 meq = PC, 18 meq
CEC7, 16 meq = PC, 12 meq
CEC7, 19 meq = PC, 5 meq

Note: Relationship between CEC7 and PC is not linear.

B. Nomenclature of great groups and discussion on properties

1. "Kand" or "Kandi" depends on phonetic consideration. Kanditropept, but Kandudult.

2. The prefix "Kand" indicates a dominance of low activity clay which in most cases is kaolinite. Presence of halloysite in high amounts will also give a low CEC, which is the property which we wish to emphasize, so it is not a problem with respect to the use of the prefix. Soils with high amounts of low charge micas (clay size muscovite) will also come into this great group. These two cases are not common and may be included in the concept of "Kand" without distortion.

3. Use of CEC7 of 24 for Kand great groups is not recommended, and I prefer 16. The latter is equivalent to a PC of 12.

4. I get the impression that you wish to tie in Smith's clay increments to the definition of the Kandudults. I still disagree. I fear that there will be conflicts with Paleudults and Arenic and Grossarenic great groups.

C. Plinthite, petroplinthite, and petroferric contact

The discussion on this seems to be taking a merry-go-round. G. Smith and S. Buol have asked what my concept is and so I am elaborating here.

Basically plinthite, petroplinthite, and the petroferric contact are features which are distinct expressions of three stages of a single process--the absolute accumulation of iron in soils. Each indicates a particular stage in soil formation, but each, however, requires a specific environment to form and remain. All require an external supply of iron which accumulates in specific parts of the soil matrix. All are invariably associated with a present or a past ground water-table or laterally (downslope) moving water.

I have tested the hypothesis that one or other should have more crystalline iron forms or larger crystals of goethite or hematite or different types of crystalline iron forms, but to no avail. The total iron content is also not a differentiating property as it is a function of the original matrix composition. This also rules out bulk density. Total free and active iron or their ratios are of no use. The only parameter available is morphology. Micromorphology is also helpful.

1. Plinthite

Segregation of iron in the soil by a fluctuating water-table may result in a varigated horizon composed of interconnected domains of iron rich and iron deficient parts of the soil matrix. The term plinthite is employed to refer to the iron rich parts. Plinthite is generally not a discrete entity in the sense that it can be picked out of the soil material, but when compared with the iron poor parts of the matrix, it is contrasting enough to be considered as a distinct material. The plinthic material is present as interconnected streaks on the pedon wall; the streaks being generally vertical. The volume occupied by the plinthite generally decreases with depth until a layer which is almost completely pale is reached.

There is generally at least one unit of hue difference between the plinthite and the enclosing soil material, and the value and chroma is 4 or more. The matrix of the horizon in which the plinthite occurs is homogenous in all respects except for color and free iron. The plinthite is soft--it may be scratched by a fingernail.

Generally plinthite forms in materials with low activity clay, but this need not be so. Its presence indicates a relatively stable surface. Holocene surfaces in Malaysia have sesquioxidic nodules but no plinthite; presence of plinthite indicates an older surface. Rapid fluctuations of ground-water leads to concretion formation (?) and so plinthite formation requires other conditions. The fact that it is not hard indicates that the soil is not dry for prolonged periods.

2. Petroplinthite

Unlike plinthite, the petroplinthite is hard--it does not break under pressure between the fingers and is not scratched with the fingernail. All transitions between the two are possible and it is necessary to draw a limit.

Hardening of plinthite appears to take place in a centripetal manner--from the core outwards. In the hardening process there is a tendency to form discrete entities. Initially a hardened core is surrounded by softer material. For purposes of Soil Taxonomy, this is still considered as plinthite.

The petroplinthite is only formed when an outer crust of about 0.2 to 2 mm thickness develops. The crust may enclose one or more of the hardened cores with or without the enveloping soft materials. The resulting petroplinthite is irregular in shape. Crust formation implies a secondary supply of iron.

Plinthite need not be a precursor to petroplinthite. Mottles, sesquioxidic concretions, nodules, and thick argillans may also act as precursors or nuclei for petroplinthite formation. The crust as seen in thin-sections is usually pure iron. This indicates that there was a large supply of iron, perhaps for a very short period. The iron engulfed all such features. If there was more than one such flux of iron, primary petroplinthite is recemented to form compound features. This building up process may continue to form large blocks.

The most characteristic feature of petroplinthite is that it has a hard outer crust which is only a few mm thick. The petroplinthite may be gravelly, stony, or as large blocks, but the important feature is that it is not a continuous feature in the soil. It is not a barrier to roots, as they can go around it. It is not a barrier to moisture percolation. It is only an obstruction to mechanical cultivation. When thick layers of transported, gravelly, petroplinthite forms the soil, the uprooting of trees is a common phenomenon due to poor anchorage.

3. Petroferric contact

This may form after the plinthic or petroplinthic stage. Again there is a large rapid flux of iron. The iron recements the petroplinthite, forming an impervious layer. The cement is frequently laminated indicating several fluxes of iron.

The result is a horizon that is continuously cemented in a horizontal layer, preventing root penetration, causing surface stagnation of water and ultimately resulting in the erosion of the surface material and exposing the petroferric contact at the surface.

4. Conclusion

Thus plinthic, petroplinthic, and petroferric contact are three diagnostic features of the soil requiring three specific soil conditions and environments to form and persist. These are pedological features of importance to the use of the soil.

At what level should these be brought into Soil Taxonomy? If plinthite is to be down-graded to subgroup then one could argue that other features like fragipan, duripan, or densipan do not also deserve the great group position. This chain reaction may be disastrous, and I would avoid it. Apart from that, plinthite is a feature that is easily identified and so is a useful differentiating criteria. Nevertheless, there is a need for a petroplinthic and petroferric subgroup. The latter is provided in Soil Taxonomy, and I have included the former in my proposals.

(Circular letter no. 6, being purely administrative, has been omitted.)

Circular Letter No. 7, April 1977

A. Ferrallitic Soils and Soil Taxonomy

In Soil Taxonomy, pp. 438-441, a correlative table is given between the French classification (INRA) and units of Soil Taxonomy. Most well drained Ferrallitic soils are correlated with Oxisols, some with Inceptisols, while the "lessive" or leached group of the Ferrallitic soils with low base saturation with Ultisol. Our studies of the last six years have indicated that many--if not most--Ferrallitic soils of West Africa have an argillic horizon, while at the same time having undergone the process of "ferrallitization" of the French pedological literature. While in Paris on my way to Africa, I have discussed this seeming discrepancy with ORSTOM colleagues, in particular with committee members F. Segalen and A. Perraud. We concluded that in the 1967 INRA genetic classification of the Ferrallitic soils the presence of an argillic horizon (and the processes leading to the formation of such an horizon) was relegated to a low level in the classification. At present ORSTOM researchers are well aware of the occurrence of an argillic horizon (and the process of lessivage) in most Ferrallitic soils. Hence, it was concluded that Ferrallitic soils are comprised of Oxisols, as well as most "Kandi" great groups of Alfisols, and Ultisols exclusive of those with an aquic moisture regime. Some of the low activity clay soils in other orders, especially Inceptisols, may also belong to Ferrallitic soils of the French classification. Recognition of soils with an argillic horizon as separate taxa (group level) in a revised French classification would open the door to an improved correlation between the two systems, provided that the diagnostic characteristics are either equivalent or related.

B. The demise of the temperature regime limitation for the kandi great groups

This hotly debated subject (circular letter nos. 1, 2, 3, 5, and keys of Kandiudults) can now be considered closed, thanks to correspondence from G. Smith, and especially to the work of the Committee on Amendments to Soil Taxonomy--Southern States. Smith writes in his letter of 17 December 1976:

Now I am going to surprise you. If the temperature limit were to be removed, the main impact on the U.S. classification would be to change the name of Paleudults on the Atlantic coastal plain, and possibly leave some of those in the Mississippi valley as Paleudults. The Ruston and Norfolk series might be split, but as Dr. Buol points out, perhaps they should be split. To be safe, I suggest we offer two definitions, one with and one without the temperature limit. The present Hapludults would mostly be unaffected because their CEC is too high, or because there are too many weatherable minerals. I do not think that this situation would prevent acceptance of the committee's proposals, so I withdraw my suggestion that we have a temperature limit on Kandiudults! You may recall my position was based in part on concern over rejection of our proposals if we seriously disturbed the classification of the U.S. soils. This concern becomes tolerable with your proposed restrictions on weatherable minerals and CEC.

Kandiustults would be extensive in S. America and possibly S.E. Asia but not in N. America, so the decision to use or not use temperature limits would not affect the classification of the U.S. soils. Similarly, Kandiustalfs would be extensive in Africa and Australia, but do not occur in the U.S. to any significant extent. Kandixeralfs already have a built in temperature limit, that of the xeric moisture regime, and could not be as warm as hyperthermic nor could they have an iso-temperature regime. They may occur in Australia. Very few, if any, of the kaolinitic Xeralfs of California would meet either of the CEC limits proposed for Kandiudults.

These data are largely confirmed by the summary of the Southern States study on the subject, which follows:

Summary of the break of pedons in the Southern U.S. when a CEC (NH_4OAc) limit of 24 meq/100 g clay is introduced:

Pamlico Terrace--20 pedons, all above 24 meq/100 g clay;

Talbot Terrace--8 pedons, all above 24 meq/100 g clay;

Upper Coastal Plain--98 pedons, 57 pedons with at least 1 horizon with <24 meq/100 g clay;

Tennessee--56 pedons, 19 pedons have at least 1 horizon with <24 meq/100 g clay;

Kentucky--19 pedons, 2 pedons have 1 horizon each with <24 meq/100 g clay;

Arkansas and Oklahoma--6 pedons, all with 24 meq/100 g clay;

<u>Total</u>

156 pedons

83 pedons have <24 meq/100 g clay in at least 1 horizon

18 of these 83 pedons have the horizon or horizons with <24 meq/100 g clay below the textural control section

8 series are represented with >24 meq/100 g clay.

At Orlando this subject was further discussed, both in committee and elsewhere, and it was agreed generally that no temperature limitations should be introduced in the definitions and keys of the Kandi great groups. This, therefore, is the final word on this subject; the keys of circular letter no. 5 will have to be revised accordingly.

C. "Active" versus "non-active" oxides, mainly iron oxides

In circular letters nos. 3 and 4 it has been pointed out that there are important behaviour and management differences between low activity clay Alfisols and Ultisols, and that soils which have been developed from materials high in ferro- magnesium minerals (e.g. basalts, amphibolites) show in general a superior physical behaviour than those from more acid parent materials. Partly, this is reflected in Soil Taxonomy, notably in the Rhodic great groups and subgroups. It was also pointed out that these rhodic taxa do not necessarily have an oxidic mineralogy (Soil Taxonomy, p. 387). Work on the nature of the activity of oxides in soils with low activity clay, in which our members Goro Uehara, Adrien Herbillon, and Tony Juo are involved, seems to indicate that the specific surface area of Fe and Al oxides is a key factor in the differentiation of the two kinds of "low activity clay soils." The following table, from Gallez et al. (Soil Sci. Soc. Amer. J. 40:601-608) may illustrate this.

Table 1. Calculated surface area of Fe_2O_3 in soil clays.

Parent rock	Soil/horizon*	Fe_2O_3 g/g clay	Specific surface area** SO	SR	A
Basalt	Tropohumult B21t	0.14	85	46	324
Gneiss	Paleustalf B2t	0.15	45	40	73
Sedimentary	Paleustult B21t	0.13	34	32	47

* All soils would become kandi great groups.
** SO = Surface area of soil clay by N_2 adsorption.
** SR = Surface area of residual clay after dithionite treatment.
** A = Derived surface area of Fe_2O_3 in m^2/g.

Unfortunately, this kind of determination of BET-specific surface area is difficult, and could hardly be proposed as a routine method for determination of a diagnostic property. Moreover only a few soils have been studied, certainly not enough to draw the diagnostic line between "high" and "low" active Fe oxides. Nevertheless, T. Juo remarks that it is the surface activity of the Fe_2O_3 rather than the total amount present in the soil that is critical for such chemical and physical properties as phosphate sorption, bulk density, and permeability.

Fortunately, the specific surface area of the Fe oxides appears to correlate with other values, which are easier to determine. In an article submitted to Soil Science, Juo and Fox indicate that there is a high correlation between P sorption capacity and specific surface area measured by N_2 adsorption. Correlation coefficients are given in Table 2 for some soils in our sphere of interest.

Table 2. Correlation coefficients between P sorption capacity and BET-specific surface area (BET-SA).

Soils	Corr. coeff.
Alfisols from acidic rocks	0.98 **
Ultisols from acidic rocks	0.97 **
Alfisols and Ultisols from basic rocks	0.88 **

**indicates highly significant

Based on the silica solubility and sorption data from some low activity clay Alfisols and Ultisols, Gallez et al. (SSSA J., submitted) indicate that the index of silica reactivity (ISR) at pH 9.2 is also highly correlated with the BET-SA. According to A. Herbillon this is an easy determination, lending itself to routine work.

All this work, I have to repeat, has been done only on a few soils, carefully classified according to Soil Taxonomy, and many more determinations on various soils are required before the content of "active" Fe oxides or a correlated value can be recommended as a diagnostic criterion. Nevertheless, it is urged that more data on critical soils be produced; for methods involved, please contact the knowledgeable members, especially A. Herbillon and T. Juo.

Classification-wise, I foresee the following points which should be raised:

1. Is the effect of a--yet to be determined--high content of "active" Fe oxides sufficiently important as regards soil properties and related management properties, to warrant the recognition of such soils as separate taxa? My own opinion would be affirmative, such a separation might shed more light on the seeming discrepancy which evolved from G. Uehara's list of properties, appended to circular letter no. 3. Recently I keyed out two soils, respectively from olivine basalt and from old sedimentary materials as clayey, kaolinitic, isohyperthermic Typic Kandiudults, and I can assure you that the two are alike only in name, and differ greatly as regards management behavior and agricultural potential.

2. If the previous statement is accepted, would it be possible that such soils could be grouped with "Rhodic" taxa, provided that the definition of "Rhodic" would include the additional or alternative high active Fe oxides diagnostic property?

3. In general: should the soils with high active Fe oxides be separated early from our more "normal" Kandi groups, i.e. should we work towards excluding them by introducing an excluding diagnostic property?

I might point out that from early days the treatment of the classification of soils on materials derived from basalt and other basic and ultra-basic rocks has worried me. Such soils, predominant for instance in Hawaii, are very different from soils with the same name but on more acid materials. The same is true for the Nitosol nomenclature in the FAO/UNESCO legend which initially were meant to distinguish the soils with "shining ped surfaces" from basic rocks, but which by now include large areas of quite different soils related to more acidic rock types. The discussion on this topic remains open, and your comments are requested.

D. A thin oxic horizon over an argillic horizon

Reference is made to circular letter nos. 2, 3, 4 and the draft key of Kandiudults in 5. As Soil Taxonomy stands now, a soil with an oxic horizon of more than 30 cm becomes an Oxisol, irrespective of the underlaying horizon, which may be argillic. This occurs most common in soils with a udic or perudic soil moisture regime, but it may occur also under other moisture regimes, as some of you have indicated. A typical case is described by Gamble et al. (1970 SSSA Proc. 34:276-281) for North Carolina. On this topic, G. Smith writes:

> Circular letter no. 4 p. 36, 2., This section concerns the thin "oxic" horizon that lies on an argillic horizon. I had not anticipated that this would become a problem because I thought the problem horizon would be considered a subhorizon of the argillic horizon. On p. 38 (Soil Taxonomy, Oxic horizon) column 1, about the center, I wrote "If there are clay skins in pores and on peds somewhere within the soil, the relative increase in clay content within a vertical distance of 30 cm is less than that required for the argillic horizon." This is followed by several explanatory sentences, but did not get into the summary. If the clay increase at the top of the oxic horizon is inadequate for an argillic horizon, the only way that one could be present would be to have the clay increase at the base of the oxic horizon. In other words, the oxic horizon would be in the position of an A_2 or A_3 horizon. If this is the problem, the oxic horizon could be expanded a bit to require a minimum thickness of 30 cm if underlain directly by rock (normally limestone) or by a horizon containing weatherable minerals or more than 5 percent volume of saprolite. The minimum thickness could be something like 75 or 100 cm if underlain by a horizon having the properties of an argillic horizon. Not knowing the soils, I do not know what the thickness should be.
>
> Circular letter no. 4 p. 37, 3., My suggested change in definition of the oxic horizon might eliminate the need for change proposed by H. Eswaran in item 2C (circular letter no. 3, p. 21) of my original proposal. The change proposed here in thickness of an oxic horizon would push the boundary between the oxic and argillic horizons on the average to something more than 1 m if the thickness of the A1 is added. One meter of loamy or clayey completely weathered soil material might result in more accessory properties to the oxic horizon than to the argillic horizon. The change in definition of the oxic horizon would greatly simplify the definition of Ultisols and Alfisols.

This change in the definition of the oxic horizon was discussed in Orlando; it seems a way out of part of our difficulties with the argillic horizon. R. Tavernier made an alternate proposal, leaving the definition of the oxic horizon unchanged, but whereby the definition of Oxisols (Soil Taxonomy p. 323) would change by adding a third requirement:

"3: Do not have an argillic horizon within 125 cm from the soil surface and an overlying oxic horizon of less than 60 cm." This approach would also require a change in the definitions of Alfisols and Ultisols, as follows: Alfisols (Soil Taxonomy p. 96 point 6 of the definition): "Do not have an oxic horizon which is 60 cm or more overlying an argillic horizon .....", and Ultisols (Soil Taxonomy p. 349 point 3 of the definition): "Do not have a spodic horizon, and do not have an oxic horizon of 60 cm or more unless ....."

Corresponding changes would be required in the key to soil orders (Soil Taxonomy pp. 91-93) and in the sections dealing with limits between Alfisols, Ultisols, and soils of other orders. All thickness limits proposed are tentative and have to be tested. The consequence of the above, if accepted and properly defined would be that the proposed keys of circular letter no. 5 will have to be revised. It appears that a subgroup with a "thin oxic horizon" will have to be recognized, and that such a characteristic should be excluded from the typic subgroup. Whereas the Smith-Tavernier proposal brings in an entirely new element, I would request your comments before presenting a revised key.

E. CEC, Base Saturation, etc.

A letter of G. Uehara regarding the appendix to circular letter no. 5 is given in appendix 1 to this letter. This matter is recommended for the panel discussion in the Brazil meeting, and it is hoped that the panel can come up with a recommendation as regards definitions of charge characteristics and base saturation inasmuch as they are relevant to our work.

From R. Isbell, A. Perraud, P. Segalen, T. Juo, and also from the Wageningen Department of Soils and Fertilizers (F. Koenigs), remarks and studies were received regarding the use of various CEC and base saturation values as diagnostic criteria. There is little consensus, although the use of the KCl CEC (ECEC) and the corresponding KCl BS is preferred by several discussants. It is pointed out repeatedly that the existing method (NH_4OAc CEC) is unsatisfactory in soils with colloids in which surface charge varies with pH and electrolyte concentration. Methods of determination are subject to considerable errors, e.g. with the alcohol treatment in the determination of the NH_4OAc CEC.
P. Buurman from Indonesia contributed with a series of regression analyses

between the NH_4OAc CEC and PC, the results of which make it clear that in that country, relations are strongly locale-specific, mainly as a function of the nature of the parent material.

It is also clear from the various contributions that the amount of exchangeable Al as a percent from either PC or ECEC is considered an important property to distinguish (low activity clay) Alfisols and Ultisols, but there is no agreement as to which diagnostic percentage should be adopted.

G. Smith, while discussing the keys of circular letter no. 5 remarks that the limit of 12 meq cation retention from NH_4Cl per 100 g clay does not work for a great many Puerto Rican soils. He suggests that instead, a diagnostic value of 12 meq PC (sum of bases plus extractable Al) be used. Personally, I believe that a higher diagnostic PC value (e.g. 16) might be more advantageous; this is based on data we have from S. Nigerian soils.

In appendix 2 to this letter, a review is given by G. P. Gillman from CSIRO on the measurement of charge characteristics of soil, for your information and discussion.

All in all it appears that our present diagnostic values, related mainly to the NH_4OAc CEC and BS are likely to require changes. But which changes should be introduced is anything but certain, mainly because too few data from low activity clay Alfisols and Ultisols are available. Until such is the case, it is proposed to maintain the 24 meq NH_4OAc CEC per 100 g clay for the "Kandi" great groups and to leave the BS values used for distinguishing Alfisols from Ultisols unchanged.

F. <u>Plinthite, Petroplinthite, etc.</u>

From letters and from discussions such as those held in Orlando, more information was gathered on the importance and distribution of plinthite and its hardened forms. R. Isbell writes:

> My general reaction would be to key the Kandi great group out immediately after Fragi great groups and relegate Plinth great groups to the subgroup level, as you have done for the Petroplinthic subgroup. Like you I do not find plinthite normally restrictive to plant roots. However, it would be fairly rare in Australian soils of my experience to find plinthite within 1.25 m of the surface. It would commonly occur in some Kandi great groups but seldom within 1.25 or even 1.5 m of the surface. In contrast, petroplinthite (and I like the idea as proposed by H. Eswaran, circular letter no. 5--Appendix) would usually occur at shallow depths and thus would form an important and desirable subgroup.

From G. Smith comes the following comment:

> I have a paper in preparation on an ironstone that grades into plinthite at depths of 1 m or less and that has tubular channels filled with clayey material in such a manner that the ironstone conducts water and allows grass roots to grow into the underlying plinthic horizon. The grasses do not reflect its presence at depths of 2 cm or more but the trees are stunted and deformed if it is shallow. I am going to propose the name lithoplinthic horizon for it and propose its use at the subgroup level in Soil Taxonomy. It can be considered as a soil parent material as well as a horizon. The underlying plinthite rich material (under the lithoplinthite) where I have seen it does not seem to restrict water movement or roots. Nor did I see any evidence of such restrictions in the Plinthustults or Plinthudults. My observations of a few soils would confirm yours.

At the Orlando meeting, it was pointed out, that the restrictions of root growth in plinthite horizons are probably more related to a high Al saturation than to a mechanical impedence. This information is in addition to what has previously been said on the subject, and relevant mainly as regards to the correct place of the Kandi great groups. The discussion on the topic remains open.

G. Other

G. Smith discusses soils which he, C. Sys, and A. Van Wambeke (Pedologie 1975, 1 p. 5) classified in Zaire as "Oxic Paleudults." These are soils that have a thin argillic horizon over what appears to be a thick oxic horizon. The clay skins are most distinct directly below the Ap and disappear with depth. Such profiles are believed to be the result of cultivation, according to Sys. They would wind up in the Kandiudults, but should be placed in separate "Oxic" subgroups. I believe that more information is required, and perhaps C. Sys could send me additional data.

Appendix 1 to Circular Letter No. 7
(Contribution of G. Uehara)

Comment on circular letter no. 5, appendix 1

I would like to make the following suggestions to the appendix 1 to circular letter no. 5.

A. Charge characteristics and base saturation

1-3. OK

4. Permanent charge (change to read:)
PC is the sum of the exchangeable bases Ca + Mg + Na + K plus KCl Al at the isoelectric point expressed on 100 g clay or soil.

The basis for this suggestion is as follows:
The total charge on soil or clay is

$$\sigma_T = \sigma_{pH} - \sigma_P$$

where σ_T is total net charge in meq/100 g, σ_{pH} is pH dependent charge and σ_P is the permanent charge. The negative sign preceding σ_P assumes that all permanent charge is negative. σ_T is the sum of bases plus KCl Al and consists of the sum of σ_{pH} and σ_P. σ_T equals σ_P only when σ_{pH} is = 0. σ_{pH} is equal to zero (net zero) at the isoelectric-point (IEP or pH_0) of the pH-dependent charge minerals.

When $\sigma_T = 0$, $\sigma_{pH} = \sigma_P$. At this point net total charge is zero but there is an effective CEC entirely attributable to permanent charge. In other words, there is a measurable ECEC which is associated with an equal pH-dependent anion exchange capacity (AEC). When $\sigma_T = 0$, we say that the soil is at its zero point of charge (ZPC). ZPC implies net zero charge so that there are equal numbers of negative and positive sites. The invariant negative charge sites at ZPC or IEP are assumed to be due to permanent charge (PC).

We can therefore conclude that the sum of bases plus Al is related to permanent charge only when σ_{pH} is zero or positive. In practice this condition is met when delta pH or (pH in 1N KCl - pH in water) is zero or positive.

Technically a soil which is composed entirely of pH-dependent charge colloids (e.g. pure hematite) will adsorb cations even at its isoelectric point. This occurs because even at the isoelectric point you have specific adsorption of di- and trivalent cations, and in addition some pH-dependent positive charge.

Thus the "permanent charge" measured at pH values at or below the isoelectric point is slightly larger than the true permanent charge. In Andepts this discrepancy can be very large, but in Ultisols, quite small. We have no data for Alfisols.

The definitions of zero point of charge (ZPC) and isoelectric point (IEP) are crucial.

1. Zero point of charge (ZPC)
   ZPC is the pH corresponding to net zero charge of a soil containing mixtures of pH-dependent and permanent charge minerals.

2. Isoelectric point (IEP or pH_0)
   Isoelectric point is the pH corresponding to net zero charge of the pH-dependent charge component.

Note that ZPC = IEP when there is no permanent charge mineral.

If the revised definition of PC is accepted then the definitions of pH-dependent charge (PDC) and charge ratio are also revised.

8. pH-dependent charge (PDC)
   PDC is the difference between ECEC (σ_T) and PC (σ_T at $\sigma_{pH} = 0$).

9. Charge ratio (CR)
   CR is the ratio of PDC to PC.

The ratio of extractable acidity at PC should be high in low activity clays and low in high activity clays.

Appendix 2 to Circular Letter No. 7
(Contribution of G. P. Gillman, CSIRO)

In recent years there has been a spectacular increase in soil science research in the tropical regions of the world. Chemists and mineralogists working with tropical soils have come to realize that for many of these the analytical procedures developed for soils from the temperate regions are not directly applicable. This is especially true in the area of surface charge characterization and in particular in the determination of the cation exchange capacity (CEC).

Much of the early work on CEC involved the use of pure clays of the 2:1 type or of soils dominated by such clays, where the surfaces are negatively charged because of isomorphous substitution within the clay lattice. Such soils are of course present in tropical regions. The determination of CEC is straightforward because the surface charge is relatively independent of pH and electrolyte concentration and hence a variety of methods will produce essentially the same result.

Many tropical soils, since they occur under warm, humid conditions, are dominated by kaolin clays and sesquioxides. These soils are not, of course, found exclusively in tropical regions. The surface charge on these materials can be greatly influenced by the pH and electrolyte concentration of the medium surrounding the surface. Hence a variety of estimates of CEC can be obtained depending on the method used.

Cation exchange capacity and base saturation are important in the major world soil classification systems. Perhaps there are three criteria which should be applied to the choice of methods of determining CEC (and there could be others):

1. the determination should be applicable to all soils, irrespective of the clay mineralogy;
2. the precision of the method should be sufficient to satisfy the delimitations set by the classifier; and

3. though not essential for classification per se, the method should allow meaningful agronomic interpretation.

In the U.S. system, one of the common methods of determining CEC is to saturate the soil with a 1N solution of NH_4^+ at pH 7.0, wash out the free NH_4^+ in solution with alcohol, displace the NH_4^+ held on the soil by using another cation, and measure this displaced NH_4^+. The method for the FAO system is similar, sodium acetate being used instead of ammonium acetate.

Such methods are not applicable to kaolinitic and sesquioxidic soils because:

1. the pH and electrolyte concentrations are quite different to what would be encountered in the field;
2. the precision of the method should suffer because the alcohol washing step would be difficult to reproduce exactly, and the method and amount of washing will greatly influence the surface charge; and
3. there is the possibility of specific adsorption of acetate, which will increase surface negative charge.

It is becoming obvious to chemists that any method for estimating the cation exchange capacity of these soils must be related to field conditions, and phrases such as effective cation exchange capacity are being used. One proposal is to displace the exchangeable basic cations with, say, NH_4^+, and sum them with the exchangeable acidic cations displaced with 1M KCl.

Unbuffered solutions are used so that the estimation is meant to be carried out at the soil pH. Unfortunately, in sesquioxidic soils, a 1M KCl solution can alter the soil pH by as much as a full unit. It is thought that the increase in electrolyte concentration causes an increase in surface charge and if the soil is already net negatively charged, this is accomplished by the adsorption of OH^-. The additional H^+ left in solution would be measured as exchange acidity, thus causing an overestimation of CEC.

Attempts to obtain statistical correlations between the various analytical methods must surely be a temporary measure, since what is needed is a standard universally accepted procedure. It is difficult to achieve uniformity within geographical boundaries let alone going beyond them, but I would like to propose that a method researched by a group of interested workers might command some respect. The members of the Committee on Classification of Alfisols and Ultisols with Low Activity Clays would be in contact with chemists interested in this problem, and hence this Committee might be willing to foster this research.

A. Appendices

The main information for discussion in this circular letter is given in the appendices to this letter. They are given in the order that the material reached me.

Appendix 1 is a note on the textural profiles of tropical Oxisols, Ultisols and Alfisols by J. Bennema. Consideration of the various processes leading to textural differentiation and loss of clay from the surface horizons appear of particular importance to our discussion of argillic horizons.

Appendix 2 deals with the "lixic" or "luvic" horizon as an intermediate form between the argillic horizon and the oxic horizon of Soil Taxonomy. The write-up is by W. Sombroek; some preliminary comments are in, but I would rather deal with these after receiving further reactions.

Appendix 3 by R. Isbell touches upon a subject which has been and still is a serious controversy among committee members. It pertains to the role of the argillic horizon in Soil Taxonomy, its expression, and the difficulties met with in defining an acceptable limit between Oxisols and (low activity clay) Alfisols-Ultisols. This is a recurrent point of discussion, as it became clear in both the Brazil and Malaya meetings.

Appendix 4 is a letter from T. Juo, who has gone through a considerable amount of data to establish relationships between the NH_4OAc CEC and the ECEC.

Appendix 5 is a proposal by J. Bennema and J. Comerma dealing with the boundary of Kandi great groups and Oxisols, including changes in the definitions of oxic horizon, Alfisols, Ultisols, and Oxisols. The proposal is an important new approach, but it requires much more study as regards the precise implications.

Following the guidelines of the Bennema-Comerma proposal, the profiles of the Brazil tour which would be Oxisol are BR 7, BR 14, BR 16, BR 21, and BR 23 (?).

Of these, only BR 16 and BR 23 had been called Ultisols during the field tour; as regards BR 23 there is a ratio 1.33 between B1t and A3, but one of 1.66 between B1t and A1. One profile, BR 24, would cease to be an Oxisol, as classified during the field tour.

The proposal would not change the classification of any of the 23 low activity Alfisols and Ultisols in S. Nigeria on which in-depth analytical studies had been performed, since all of these soils had sufficiently more clay in the B, as compared to the overlying horizons, to exclude them from Oxisols.

Less satisfactory was the application of the proposal to the analytical data of Zaire profiles (C. Sys, 1972: Characterization Morphologique et Physico-Chimique de Profiles Type de l'Afrique Centrale, INEAC, Brussels), as classified according to the taxonomy used in Soil Taxonomy (G. Smith et al. 1975-1, pp. 5-24).

Following the data on texture and equaling Sys' TCa with CEC_7 by NH_4OAc (?) in 100 profiles of Oxisols for which the data were sufficient for interpretation, 77 of the 100 keyed out as Oxisols according to the Bennema-Camargo proposal while 23 became Ultisols. Of a selected 26 "Pale" Ultisols and Alfisols 11 may classify as Oxisols according to the proposal, but interpretation of the data is less certain. C. Sys may wish to comment on this interpretation; it would be appreciated if other committee members, apart from their comments on the Bennema-Comerma proposal, would try its application on their own profiles and would share their findings with the committee.

Personally I believe that in terms of field diagnosis of the boundary between Oxisols and the low activity clay Alfisols and Ultisols the proposal would simplify matters. It requires, however, more work to fit it in the present Soil Taxonomy syntax, and a number of points need additional clarification. I am contacting J. Bennema in this respect and hope to treat the subject in depth together with the committee's remarks, in the next circular letter. One general point of difficulty in the proposal seems to me to be that "low activity Ultisols and Alfisols" in the Pale groups may change to Oxisols by the simple expedient of erosion of the lighter textured surface layers, a not uncommon occurrence. This appears somewhat against the trend in Soil Taxonomy, where, with a few exceptions, less emphasis is laid on the surface horizon for the higher category classification (exception, Mollisols). However this may be, there are many positive aspects to this new proposal.

B. Conclusion

This circular letter with appendices is mainly informative, and to some extent polemic, inasmuch as it indicates some of the controversial opinions among our members. I did not find the time for elaborating any compromise proposals, nor does that seem possible at the present because of a thorough lack of consensus on several points. We need more data, more testing of alternative ideas, and more work certainly.

Appendix 1 to Circular Letter No. 8
(Contribution of J. Bennema)

A. Note on the Textural Profiles of Tropical Oxisols, Ultisols, and Alfisols

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Oxisols, Ultisols, and Alfisols have in general a coarser texture in the topsoil than in the subsurface soil. The clay percentages increase with depth, the coarse sand to fine sand ratio increases also in many profiles.

Material greater than 3 mm is, however, mostly absent in the surface layers of most tropical soils. It is only present in cases of exceptional erosion. Otherwise it is often found in a stoneline or layer.

The processes involved in the genesis of these texture profiles are:

1. splash and sheet erosion with a preference for fine particles;
2. illuviation of clay;
3. breakdown of clay particles in the upper layers as a fast process mostly related to pseudogley;
4. breakdown of clay particles in the upper layers as a slow process (related to chelating?); and
5. these processes of differentiation are counteracted by the process of mixing of particles <3 mm by ants, termites, and earthworms.

In typical well-drained Oxisols only the processes of erosion, breakdown of clay particles as slow process, and mixing are involved.

The data on the chemical composition show that molecular SiO_2/Al_2O_3 ratios (of extractable SiO_2 and Al_2O_3, thus without quartz) are higher in the topsoils than deeper down. This can only be explained by a greater loss of Al_2O_3 from the topsoil (loss of kaolinite by illuviation or erosion would lead in these soils with a SiO_2/Al_2O_3 ratio lower than 2 to a decrease in SiO_2/Al_2O_3 ratio). This loss is presumably due to a chelating or solution process.

The observation that the coarse sand/fine sand ratio is often higher in the topsoil of many Oxisols than in the subsurface soil is an indication that erosion also plays a role.

The frequently high activity of animals which transport soil materials is well known in most tropical soils.

The author believed formerly that in particular the chemical breakdown of clay minerals in the top layers as responsible for the clay profiles of Oxisols. Results from many calculations indicate, however, that erosion is often the most important agent together with mixing.

Surfaces of Oxisols are mostly old and the influence of the time factor can be easily underestimated. Very weak erosion has a strong influence over a very long period.

For calculations profiles could be used which were described and analyzed by the Servico National de Levantamento e Conservacao de Solos, Rio de Janeiro. Those profiles which have a sand fraction consisting of almost 100% quartz are especially convenient to use. If quartz sand or coarse quartz sand is used as a reference then it appears that 40 to 50% of the clay fraction disappeared from the top layers. About the same percentages of SiO_2, TiO_2, and Fe_2O_3 disappeared, but the loss of Al_2O_3 is somewhat greater. This can be interpreted as a loss of equal percentages of all the elements present by erosion with an extra loss of some Al_2O_3 due to solution or chelating.

The loss by erosion is especially acting on the soil surface. The mixing leads to the slow increase of clay with depth, typical for many Oxisols. The very gradual increase is a function of the relatively high intensity of mixing against the relatively slow loss of fine materials from the soil surface. Without strong mixing or with a stronger loss of fine particles the increase in fine particles would become less gradual.

A check on the theory that erosion has influence can be found in the behavior of Fe_2O_3 and TiO_2. In the Brazilian soils mentioned above no Fe_2O_3 and TiO_2 are present in the sand fraction. Fe_2O_3 and TiO_2 disappear in this case almost in the same percentages as the other material in the clay fraction. If Fe_2O_3 and TiO_2 were present in greater amounts in the sand fraction, however, then they would stay behind, and TiO_2 and Fe_2O_3 would consequently show a relative increase in the top layers. This is e.g. the case for some profiles on basalts.

The use of Oxisols for agriculture may lead to increased sheet erosion (in particular in soils with relatively low Fe_2O_3 content) and in a decrease in biological activity. This may give rise to a more marked increase in clay content.

The processes mentioned as acting in Oxisols are also acting in many Ultisols and Alfisols. They are most apparent in deep paleo subgroups. In addition to these processes clay illuviation is (or was) acting which, often but not always, is shown by the presence of clay skins. Clay skins might, if biological mixing is relatively fast, be destroyed. The illuviation may also show in the clay bulge. This clay bulge might be in the form of an increase in clay content followed by a decrease lower down. This decrease is however not always present: if the clay bulge is superimposed on a gradual increase, due e.g. to erosion and mixing, the decrease will not show.

The process of clay breakdown as a relatively fast process acts in particular in conditions of pseudogley. Brinkman attributes the formation of planosols to this process. A (perhaps somewhat milder) form of this process might occur in imperfectly drained Ultisols. The breakdown of clay in these profiles by stagnation of water may lead to a rather abrupt increase in the clay content from A to B. Or it might show in the B of lighter-textured soils in which clay is partly destroyed, e.g. along old roots or cracks. These phenomena may be accompanied by formation of fragipans. These kinds of imperfectly drained Ultisols are probably very common in some parts of the world, e.g. in Kalimantan. It should be discussed how these soils can be set apart, and at which level.

In some of these soils the question arises also if they are indeed Ultisols. It is often difficult to decide whether the clay increase is only due to clay breakdown or if both illuviation and clay breakdown are involved.

Appendix 2 to Circular Letter No. 8
(Contribution of W. Sombroek)

The "Lixic" or "Luvic" Horizon
(i.e.: a weakly expressed variant of the argillic horizon on the oxic site)

Proposed by Sombroek, Paramananthan, Isbell, Comerma-Schargel, and Arnold.

Purpose: to fill the gap existing between the oxic horizon and a well developed argillic horizon. The latter would have at least a moderate angular blocky structure, at least common and moderately developed clay films, a firm consistence, a relatively low infiltration rate, etc.

Concept: At least 75 cm thick and/or extending to a depth of 125 cm whichever is shallower, showing no or only few ped cutans (less than 5 percent argillans, pressure faces, and/or other shiny faces), but having an appreciable increment of clay percentage (1.4 or more; B/A) that is neither abruptic nor diffuse (occurring over a distance between 7.5 and 30 cm in the A-B transition zone), while at least one subhorizon has more than 15 percent clay. The horizon has rather few weatherable primary minerals in the fine-sand fraction (less than 10 percent, excluding muscovite) and has predominantly 1:1 layer lattice silicate clay minerals (less than 10 percent of 2:1 layer lattice and/or amorphous), associated with an acetate CEC of less than 24 meq/100 g clay. The Ki-values are usually between 1.8 and 2.2.

Accessory-associated characteristics/properties (not always occurring simultaneously):

--weak to moderate subangular blocky to massive structure (possibly with weak prismatic macrostructure)
--friable when moist (neither very friable, nor firm to very firm), but hard to very hard when dry
--rather high bulk density (between 1.25 and 1.60?)
--less than total aggregate stability, as measured by the water-dispersable-clay method, in at least the upper part of the horizon (less than 90 percent with the Brazilian method)

--moderately low silt content (silt/clay ratio between 0.25 and 0.65, with some leeway for relatively sandy soils)
--relatively strong difference between moist and dry colors?

Notes (Sombroek):

1. Soils with such a weak argillic horizon are apparently common in many parts of the tropics, e.g. N. Australia (see note Isbell), Malaysia ("thin oxic over argillic" horizon), E. Africa, the Sudan belt of W. Africa, Zaire ("ultic Oxisols" of Sys-Smith), Venezuela, etc. They may also be common in Brazil, but of all the profiles examined during the workshop, only one (no. 4) would have a lixic horizon as defined.

   The A horizon of such soils are normally very susceptible to surface sealing/capping and hence sheet erosion, especially in ustic and ustic-aridic climates.

2. Soils with a lixic horizon as defined above would fall mainly in the "Kandi" great groups of the Ultisols (and Alfisols), but "Tropeptic" subgroups of Oxisols may be involved as well.

3. The Terra Roxa Estructurada (rhodic Pale-subgroups of the Ultisols and Alfisols, the Nitosols, of FAO) would not have a "lixic" horizon because of their well developed structure, high stability and their shiny ped faces--whatever they are.

4. The sandy soils (less than 15 percent clay in the B horizon) would also be excluded. They would fall largely under the Psamments (cf. the luvic Arenosols of FAO).

5. A similar variant of the argillic horizon might be defined for soils with cambic horizon. It would be similarly thick, friable, and with few or no ped cutans, but contrasted from the lixic by having appreciable amounts of weatherable primary minerals (more than 10 percent), appreciable amounts of 2:1 layer lattice clay minerals or amorphous materials, higher silt content, more structure, etc. The need for such a variant is, however, as yet doubtful.

Appendix 3 to Circular Letter No. 8
(Contribution of R. F. Isbell)

Soil Taxonomy and Tropical Soils

Experience in Tropical Australia and impressions gained from short visits to such tropical countries as Brazil, Venezuela, Columbia, Peru, Malaysia, and some subtropical countries such as Natal, and the state of Hawaii, suggest several problems in the application of Soil Taxonomy to the kaolinite-sequioxide soils of these regions.

The major problem seems to be the effectiveness of the criteria which presently separate Oxisols from Ultisols. To a large extent this involves the recognition of an argillic horizon in soils which are characterized by a gradual increase in clay content with depth, the variable presence of clay skins readily identifiable in the field, and the evidence from micromorphological studies in various parts of the world which indicate the difficulties in relating field-observable clay skins to oriented (illuviated) clay identified in a thin section.

It is suggested that because of the above difficulties the distinction between Oxisols and Ultisols in many parts of the tropics is becoming increasingly diffuse, and is very dependent on individual field operator skills and experience, and reliability of clay analysis in soils notorious for dispersion difficulties. It is evident that an increasingly large number of soils with "oxic" chemistry and mineralogy are being placed in Ultisols, based largely on the clay content specifications required for an argillic horizon, and an often intuitive guess as to whether clay skins are really present, and if so whether they indicate illuviated clay.

Personally, I do not care if we classify more soils as Ultisols rather than Oxisols, but I do think it important that the present difficulties and ambiguities in the differentiating criteria be resolved. There are a number of possibilities, e.g. all soils with strictly "oxic" chemistry and mineralogy could be placed in Oxisols by allowing the presence of an argillic horizon in the Oxisols. Another possibility would be to have a wider clay increase ratio for the argillic horizon definition in Ultisols and Alfisols and to remove the clay skin or illuviated clay requirement.

Finally, two of the aspects deserve mention. First, there is the now widely recognized difficulty inherent in using conventional CEC measurements to distinguish "oxic" soils. Second, we need to assemble available land use experience on these "oxic" soils to see if any guidelines are available for a more appropriate classification.

Appendix 4 to Circular Letter No. 8
(Contribution of the CEC A.S.R. Juo)

I am herewith enclosing the "first approximation" of the correlation between the ECEC and neutral NH_4OAc CEC on clay basis.

The data are B_2 and B_3 horizon samples from a carefully selected population of Alfisols, Ultisols, and Oxisols with low clay activity available in our soil data bank. They represent a wide range of parent material and geographic location (Nigeria, Liberia, Zaire, Kenya, Cameroon, and Brazil).

As shown in the attached figure, the data may be separated into two groups (with some imagination, of course). Group A represents soils containing predominantly well-crystallized kaolinite and "low specific surface" Fe oxides which correspond to soils derived from acidic and intermediate parent rocks, i.e., Alfisols and Ultisols derived from granitic gneisses, quartzites, coastal plain sands, etc., in West Africa.

Group B represents soils which give larger variable charges (pH-dependent and salt-dependent). Looking at the mineralogical and chemical data of these soils, it seems that three types of surfaces are responsible for the large increase in acetate-CEC values as compared to the ECEC values:

1. soils containing large amount of high specific surface Fe oxides (e.g., Alfisols, Ultisols, and Oxisols derived from basalts, diabase, amphibolite, etc.);
2. soils containing appreciable amount of amorphous Al-silicates and poorly crystallized kaolinite surfaces (e.g., Udults from Onne, Nigeria); and
3. soils containing appreciable amount of gibbsite (e.g., Ustults from sandstones in Nigeria).

Regression equations are as follows:

For group A soils $y = 3.60 + 0.97x$ $(r = 0.929)$

For group B soils $y = 7.16 + 1.27x$ $(r = 0.941)$

For all soils (A and B) $y = 6.24 + 0.93x$
$(r = 0.767)$

Where y is NH_4OAc CEC and x is ECEC in meq per 100 g of clay.

It is clear that the correlation is greatly improved when the data are separated into two groups.

Again, the use of ECEC 14 meq/100 g clay for the separation of "low activity clay" soils from "high activity clay" soils is not a bad idea (Ref. Herbillon, Gallez, Juo). This value corresponds to 17.2 and 24.9 meq/100 g clay of the NH_4OAc CEC for the group A and group B soils, respectively. Moreover, the few samples given ECEC value larger than 14 are those Alfisols containing appreciable amounts of 2:1 type clay minerals. Therefore, the "magic number" 24, based on NH_4OAc CEC, does not look like a good choice.

To further improve this correlation exercise, I would like to propose the following: (1) attach the above information to your next circular letter to committee members and those interested in this problem, and (2) request other members to send us additional data or soil samples, particularly soils from Australia, New Zealand, Malaysia, Indonesia, Peru, and Colombia.

Appendix 5 to Circular Letter No. 8
(Contribution of J. Bennema and J. Comerma)

Proposal on the Classification of Oxisols and Kandi-Taxa

A. Proposal

To transfer some of the members of the proposed Kandi great groups to the Oxisols.

It is hereby assumed that the limit for CEC/100 g clay in the definition of the Kandi great groups in the future will not be 24 meq but 16 meq as proposed in the meeting at Kuala Lumpur.

B. Objectives

1. To avoid having too many subgroups in the Kandi taxa, in particular too many "double subgroups," e.g. leptic-aquic, leptic-epiaquic, leptic-ferric, leptic-allic, leptic-arenic, leptic-psammentic, etc.
2. To make the separation of Oxisols on the one hand, and the Kandi groups of Alfisols and Ultisols on the other hand, easier to handle, without creating unsolvable difficulties in other parts of the classification system. The present separation on the basis of argillic and oxic horizons should be brought down to lower levels of the classification.
   Characteristics which can easily be dealt with in the field are preferable to "laboratorium characteristics or confusing field characteristics" like absence or presence of clay skins.
3. To enlarge the order of Oxisols with like soils. The order of Oxisols is a small one. Moreover, some of the recognized groups are of only local importance (Sombri and Gibbsi great groups). The Oxisols could be enlarged with part of Oxic subgroups of Ultisols, Alfisols, Mollisols (e.g. Oxic Paleustolls and Oxic Paleudolls), and perhaps of Aridisols (Oxic Paleargids if existing). The soils to be transferred to the Oxisols might well include non-hydromorphic and hydromorphic soils with an aquic moisture regime. The transfer of members of Mollisols and Aridisols will not further be dealt with in this proposal. This can, if needed, be studied at a later stage.

C. Proposed change in the definition of the oxic horizon

The authors of this proposal have tried to make a definition of the new concept of Oxisols without changing the definition of the oxic horizon. The new definition of Oxisols became, however, very complicated. It was therefore decided to change first the definition of the oxic horizon, and to then use the new concept of oxic horizon in the definition of Oxisols.

The change in the definition of oxic horizon reads: Delete in the present definition of oxic horizon the phrase "exclusive of an argillic horizon." No change is proposed in the definition of the argillic horizon.

Some consequences of this change in relation to Oxisols and Kandi great groups are:

1. Oxisols either have plinthite near the surface or have an oxic horizon, which in both cases might include an argillic horizon; and

2. most soils belonging to the Kandi great groups of Alfisols and Ultisols have an oxic horizon, there are three exceptions
   a. soils with too high content of weatherable minerals,
   b. soils which are too sandy,
   c. soils which are too shallow (horizon with oxic properties <30 cm);
3. the oxic horizon occurring in the Kandi great groups often, includes but not always, an argillic horizon; and
4. the soils of Kandi great groups without an oxic horizon mostly have an argillic horizon. Some sandy soils are, however, exceptions, because they do not show clear signs of clay illuviation. They do not have "an illuvial layer in which layer lattice clays have accumulated by illuviation to a significant extent" (the first sentence under argillic horizon in Soil Taxonomy). This indicates a problem in classification which still has to be resolved.

D. Definition of Oxisols and Ultisols using the proposed new definition of oxic horizons

The definition of Oxisols:

(Only second part of the definition, that not dealing with part A--plinthite near surface)

1. Soils having an oxic horizon underlying an epipedon. The upper part of the oxic horizon has:
   a. less than 6 percent more clay than the overlying horizon if this overlying horizon has less than 15 percent clay,
   b. a clay ratio of less than 1.4 to the overlying horizon if this overlying horizon has between 15 and 40 percent clay, and
   c. less than 16 percent more clay than the overlying horizon if this overlying horizon has more than 40 percent clay; and

2. one or both of the following:
   a. an oxic horizon with a clay distribution such that the percentage of clay does not decrease from its maximum amount by more than 20 percent of that maximum within 1.50 m of the soil surface, and
   b. an oxic horizon with all of the following: presence of a massive or at most weak blocky or weak prismatic structure in the B2 horizon; absence of common clear clay skins.

E. The definition of Ultisols and Alfisols

To the present definition should be added: Ultisols include soils having an oxic horizon, etc. The definition is further (etc.) the opposite of the one of the Oxisols. Read for the underlined less in the definition of Oxisols: more; for does not: does; for presence: absence; for absence: presence.

In the definition of Alfisols the same kind of changes have to be made.

F. Classification of the "transferred soils" in Oxisols

New Great groups could be formed in the Oxisols, e.g. Kurorthox, Kurustox, etc. (Kuros is younger?). For such a change in the classification of Oxisols other changes which are also thought to be necessary, e.g. creating Rhodic great groups or Rhodic subgroups, should be taken into account.

At this moment we will not deal with major changes in the classification of Oxisols, but only indicate how the pertinent soils could be classified on the subgroup level.

Formation of new subgroups or redefinition of existing subgroups may be necessary in the following great groups.
Ochraquox, Umbraquox, Haplohumox, Eutrorthox, Umbriortox, Haplorthox, Eutrustox, Haplustox, and Haplotorrox.
In the Haplorthox two subgroups are involved.

Leptic Haplorthox--like Typic but with an oxic horizon in which the clay distribution is such that the percentage of clay does decrease from its maximum amount by more than 20 percent of the maximum within 1.50 m of the soil surface.

Tropeptic Haplorthox--like Typic but with a moderate or strong structure and or with common clear clay skins.
Remark: a Leptic Haplorthox never has a strong structure or common clear clay skins, while a Tropeptic Haplorthox never has leptic properties. These soils would in this case automatically be classified as Ultisols, Alfisols, or Inceptisols. This has as an advantage that double subgroups of Leptic and Tropeptic are avoided.

G. The subgroups of the Kandiudults

The Typic subgroup of the Kandiudults was defined as the one without a strong decrease of the clay content to 1.50 m in depth. Most of the former Typic Kandiudults are transferred to the Oxisols with the present proposal. The typic subgroup is now automatically one which was formerly defined as a Leptic subgroup. This has as the advantage that fewer double subgroups occur.

Three kinds of Kandiudults without a strong decrease of clay content to 1.50 m can be recognized:

1. soils with a sharp increase of clay content from the epipedon to the subsoil;
2. soils which are too sandy to have an oxic horizon and which are not Oxisols for this reason; and
3. soils with too high amounts of weatherable minerals to be Oxisols.

The classification of these three kinds of soils merits further discussion at a later stage.

Circular Letter No. 9, June 1978

A. Comments on the argillic horizon

The topic (and consequently the diagnostic limit between Alfisols-Ultisols and Oxisols) remains very controversial. First an excerpt from M. Leamy's letter:

> A continuing concern of mine is the lingering disenchantment of some committee members with the use of clay skins as a parameter for the argillic horizon. I think it is time we came to grips with this problem by examining the basic genetic and practical reasons lying behind the selection of this criterion. One of the genetic reasons is that in soils formed in moisture regimes drier than perudic the translocation and redeposition of clay is a common process. One of the practical reasons is that translocated clay in a subsoil horizon occurs commonly in sites most accessible to plant roots, and that the translocated clay is higher in plant nutrients than the surrounding matrix. Evidence for this latter fact is not voluminous but does exist. Buol and Hole (1961) record a substantial increase in phosphorus in clay skins as compared with the matrix. In my view this is potentially a very important piece of practical information carried along with the taxonomic identification of an argillic horizon, and it could be particularly critical in the low activity clay soils. My conclusions from this are that the Committee should:
>
> 1. be extremely wary of any proposal which reduces the importance of clay skins as a parameter in argillic horizons, and
> 2. stimulate further research in the Kandi great groups to determine the genetic and practical importance of clay skins.
>
> With regard to the latter we have a research group here at Soil Bureau who are interested in mineral-organic complexes in soils and who have the skills to undertake a study of the significance of such complexes in the argillic horizons of low activity clay Ultisols and Alfisols. We would probably need support to launch such a project in practice, as much of the material would need to come from beyond New Zealand.
> I would be very interested to hear your comments on the need for such research activity. It seems to me that the Committee inevitably will continue to reveal research needs, as it has already with T. Juo's work, and I would like to see it take an active part in initiating such work.

I would like to ask for comments and suggestions, especially on the proposal for further research, as indicated in the last paragraph of Leamy's letter.

An important point made in this letter is the plea to maintain the argillic horizon as a diagnostic characteristic where the translocation and redeposition is clear and easily visible, i.e. where cutans are distinct within the taxonomically prescribed depths.

In regard to the Bennema-Comerma proposal (circular letter no. 8. appendix 5), some comments have been received by ICOMOX and are quoted in the ICOMOX circular of February, 1978.

R. Isbell does believe that the proposal "goes some way to avoiding many of our present difficulties." S. Buol is definitely against, whereby I interpret his viewpoint as meaning that a clay increase, as defined in Soil Taxonomy p. 27, la-c, should be sufficient to keep a low activity clay soil out of Oxisols, whether or not "easily detectable cutans" are present. In H. Eswaran's proposed definition of Oxisols (ICOMOX, circular 1, pp. 3 and 5) an intermediate point of view is expressed, i.e. that an oxic horizon should be at least 50 cm thick to qualify as such, and that the occurrence of an argillic horizon at less than 1 m from the soil surface would exclude the soil from the Oxisols and, hence, would relegate it to an order in which the argillic horizon is diagnostic. In an addition to his proposal, J. Bennema has amended his definition of Oxisols slightly, as follows:

"Mineral soils having an oxic horizon underlying an epipedon unless it has been exposed by truncation with the following characteristics. The oxic horizon having not more clay than the overlying subhorizon that is less than 30 cm above and is more than 20 cm thick, as follows:" (the rest of the definition follows the proposal).

Since this letter from Bennema deals mainly with the "Oxisol" side of the problem, I will transmit it to ICOMOX and discuss it with Eswaran.

I have been looking for other data to test the effects of the "textural increase rule" of the Bennema-Comerma proposal. It seems that all Oxisols described in Soil Taxonomy are genuine, with the possible exception of pedon 103 which would fall marginally under Oxisols according to Bennema and Comerma but which would not be an Oxisol following the ideas of Buol. Pedons 32, 33, 102, and 104 do not show sufficient increase in clay for either the 1.2 or the 1.4 rule, while the same may be assumed for pedons 105, 106, and 107, based on the calculated clay content of 2.5 x 15 bar water.

In Soil Survey Report No. 11 of the Republic of Zambia (H. Brammer 1973) a number of soil profile descriptions with supporting analytical data have been used for testing the 1.4 rule. It turns out that all low-activity clay Alfisols and Ultisols follow the 1.4 rule. Twenty Oxisols for which the data are sufficient split down the middle--10 would remain Oxisols according to the 1.4 rule, while 10 would disappear from this order to either Ultisols or Alfisols. When the 1.2 rule is applied even fewer soils remain as Oxisols.

Summarizing both the above data and those briefly dealt with in circular letter no. 8, covering in total well over 150 soils of low-activity clay soils (NH_4OAc CEC of less than 16 meq/100 g clay), it appears that:

1. A large proportion of the pedons show a clay increase according to the 1.4 rule and, obviously, an even larger proportion shows a clay increase according to the 1.2 rule.

2. Considering the taxonomic nomenclature of the authors of the profile descriptions, it seems that a good part of the soils classified as Oxisols would disappear from that order if the 1.4 rule became diagnostic. Even more Oxisols would lose their name if the 1.2 rule became diagnostic.

3. Considering the soils which, according to the authors, are Alfisols or Ultisols with low-activity clays, it appears that relatively few of them (perhaps 5 percent at most) would become Oxisols under the 1.4 rule, and even less under the 1.2 rule.

What this means in practice is that the introduction of a specific clay increase rule (either 1.4 or 1.2) as a diagnostic criterion to separate Oxisols from other orders would lessen the number of Oxisols. Note that in the above only the clay increase was taken into account, thereby, for this particular case, eliminating the diagnostic role of cutans, whether present or absent. Note also that the mode of formation of the lighter textured surface horizons (see circular letter no. 8, appendix 1) is not taken into account.

From the data in the profile descriptions it was simply impossible to get a clear idea whether the lower clay content in the A horizons was due to eluviation, selective erosion, clay destruction (appauvrissement), or even to the deposition of lighter textured material on the surface (lithological discontinuity).

Other parameters, such as delta pH, ZPC, structure, etc. do not seem to correlate well with the "textural profile" distinction between Oxisols and non-Oxisols among the soils studied, so that it seems that the "textural profile" of these soils is primarily an independent variable. This point, however, has to be studied in much greater depth, for which we obviously need more, and more relevant, data. Please let me have what you can collect in this respect.

B. S. Buol's letter

Appendix 1 contains a letter from S. Buol with specific proposals on nomenclature and classification of the Kandi taxa at the great group level. I would ask you to test the approach of Buol, which may well be a "step forward" towards the goal of our committee. In a next letter, and in various meetings (Edmonton, Kaula Lumpur), I hope to come back to what he has qualified as an exercise in "thinking out loud" [I might add .... "and clearly"].

C. Report on the Brazil meeting

In the original circular letter no. 9 this report was given as an appendix. It is omitted from this reprint since it has now been published in the Proceedings of the First International Soil Classification Workshop (M. N. Camargo and F. H. Beinroth, eds.), Rio de Janeiro. EMBRAPA, SNLCS, 1978 (pp. 45-63).

Appendix 1 to Circular Letter No. 9
(Contribution of S. M. Buol)

Low Activity Clay Nomenclature in Ultisol and Alfisol Keys

The following is an outline of some ideas that I have concerning the use of Kandi at the great group level and how it could be fit into the keys. My recent trip in Bolivia correlating Ustox, Ustalfs, and Ustults has influenced my thinking. All of the areas I worked in were "Kandi" by either the 16 or 24 meq/100 g clay definition except the Aqualfs.

Before reading the key, the abbreviation LAC means pH 7 CEC <16 meq/100 g clay, and the Kandic subgroup would mean <24 meq/100 g clay, as I have used them. Leptic as I have used it would be for the non-Pale, i.e. >10 percent weatherable or thin argillic criteria:

Note: I have proposed two ways of using Kandi. In the Ustalfs and Udalfs I have proposed one great group each, leaving the thin argillic as a Leptic subgroup. This has several disadvantages if there are a large number of Kandiustalfs that do not meet the Pale criteria. It would necessitate several double named subgroups such as Leptic Rhodic, for example.

In the Ultisols I proposed two great groups for each of the Udults and Ustults. I do not like the four formative element great groups (Kanhapludult, Kanpaleustult, etc.), but it seems to do the least violence to the present Pale-Haplu concepts used in the U.S. and elsewhere.

I have tried two alternatives and like them even less.

1. Using only a Kandiudult for example, as I did in the Alfisols, and you get our east coast U.S. Coastal Plain Paleudults and Piedmont Hapludults classified together until the subgroup level.

2. Since I believe that LAC is the correct model for Ultisols, it may be better to pull out the high activity clays and leave the low activity clays in the

present Paleudults and Hapludults. To do this you could define "Actudult" (Act = active for greater than 16 meq/100 g clay) in place of the "Kandi" great groups. This would also leave Cecil and Norfolk in the same great group, but makes me more comfortable with the LAC requirement for Paleudults and Hapludults as the central concept of Udults (also in Ustults).

I am sure I have neglected some items in the following outline, but I hope that you can get the drift of where different choices would leave us in the overall organization of these soils. Please look at these proposals as my "thinking out loud" so to speak because I am not locked in to any position.

One other item has recently come to our attention recently in the Southeast U.S., one that Joe and Jack will already know about, and that is the lack of any further breakdown in percent clay of clayey families in Ultisols. This apparently is a problem in engineering interpretations insofar as 35 percent clay does not behave the same as 70 percent clay, even if it is low activity clay. I think we may want to inject fine and very fine families in the Ultisols for that purpose. If so we may want to inform the LAC committee about the problem.

Low activity clay recognition in the argillic horizon

Activity of the clay must be measured in some 25 cm thick layer of the "control section for particle-size classes or their substitutes" as defined on p. 385 of Soil Taxonomy (generally 25-100 cm depth).

Possible Suborders affected

Aqualfs (very questionable)
Ustalfs
Udalfs
Aquults
Humults
Udults
Ustults
Xerults (questionable)

Possible Keying by Suborder

Aqualf: use only at subgroup level as Kandic (only if needed, of course)

Ustalf:

Durustalf: Kandustalfic subgroup of present

Plinthustalf: Kandustalfic subgroup of present

Naturustalf: Kandustalfic subgroup of present

Kandiustalf: Typic: LAC and Paleustalf requirement

Other probable subgroups:

- Aquic
- Aquic Arenic
- Arenic
- Arenic Aridic
- Aridic
- *Leptic: argillic too thin for Pale criteria of Typic (will need to be considered for criteria in other subgroups)
- Grossarenic
- Rhodic
- Udic
- Ustic

Paleustalf: other Ustalfs as presently defined

Possible subgroup changes:

Oxic: as defined would be Kandustalfic

Rhodustalf: other Ustalfs and as presently defined

Possible subgroup changes:

Oxic: as defined would be Kandustalfic

Haplustalf: other Ustalfs

Possible subgroup changes:

Oxic: as defined would be Kandustalfic

Udalfs:

Agrudalfs: Kandudalfic subgroup if applicable

Naturudalfs: Kandudalfic subgroup if applicable

Ferrudalfs: Kandudalfic subgroup if applicable

Glossudalfs: Kandudalfic subgroup if applicable

Fraglossudalfs: Kandudalfic subgroup if applicable

Fragiudalfs: Kandudalfic subgroup if applicable

Kandiudalfs: Typic subgroup meets LAC and present Pale criteria

Possible subgroups: (define as in Paleudalfs)

Aquic

Arenic

Leptic: like Typic but without the Pale requirements

Plinthaquic

Plinthic

Prammentic

Rhodic

Paleudalf: remove HEC item 1 (p. 125) to allow this great group into iso-temperatures

(possibly add Kandiudalfic subgroup for <24 meq/100 g clay)

Rhodudalfs:

Tropudalfs: (probably can delete as most would be Leptic Kandiudalfs)

Hapludalfs: (possibly add Kandiudalfic as <24 meq/100 g clay)

Aquults:

Plinthaquults: Kandi subgroup if needed

Fragiaquults: Kandi subgroup if needed

Albaquults: Kandi subgroup if needed

Kandiaquults: Typic has LAC ochric epipedons and present Pale criteria

Areic

Arenic

Arenic Plinthic

Arenic Umbric

Grossarenic

Leptic: does not have Pale criteria

Plinthic

Umbric

Paleaquults: Other Aquults are written

Tropaquults: (if not all now Leptic Kandiaquults)

Ochraquults:

Umbraquults:

Humults:

Sombrihumults:

Plinthohumults:

Kandihumults: Typic has LAC and Pale

- Epiaquic
- Leptic: like Typic except Pale
- Plinthic
- Ustic
- Xeric

Palehumults: Orthoxic subgroups to be Kandihumultic

Tropohumults: (if any)

Haplohumults:

Udults:

Fragiudults: perhaps Kandic subgroups if needed

Plinthudults: perhaps Kandic subgroups if needed

Kanpaleudults: Typic with LAC and Pale criteria

- Aquic
- Aquic Arenic
- Arenic
- Arenic Plinthic
- Arenic Rhodic
- Fragiaquic
- Grossarenic
- Grossarenic Plinthic
- Plinthaquic
- Plinthic
- Psamaquentic
- Psammentic
- Rhodic
- Spodic

Kanhapludults: Typic with LAC but not Pale

- Aquic
- Arenic
- Epiaquic
- Humic

Lithic

Psammentic

Paleudults: Typic as is, possibly add Kandic subgroup

Rhodudult: perhaps Kandic subgroup

Tropudult: (if any left over from Kanhapludults)

Hapludults: perhaps Kandic subgroup

Ustults:

Plinthustults: perhaps add Kandic subgroup

Kanpaleustults: Typic has LAC and Pale criteria

Other possible subgroups:

Aquic

Arenic

Epiaquic

Plinthic

Kanhaplustults: Typic has LAC but not Pale criteria

Aquic

Arenic

Epiaquic

Lithic (?)

Petroferric

Plinthic

Paleustult: as defined perhaps as Kandic subgroup

Rhodustult: perhaps Kandic subgroup

Haplustult: perhaps Kandic for Oxic subgroup

Xerult: Kandic subgroup if needed.

Circular Letter No. 10, October 1978

A. General

Most members of our committee were guests at the International Soil Classification Workshop in Malaysia and Thailand, 28 August to 9 September 1978. Praise should be given to our Malaysian and Thai colleagues for perfect organization and a splendid reception. To the sponsors, organizers, and participants go our sincere thanks.

The proceedings of the Workshop will report in detail the soils studied, the presentations made, and the discussions held. However, some of the most important problems with which our committee (and ICOMOX) has to cope with were solved by consensus, if not always by unanimous agreement. What evolved was a number of concepts which can be tested in the field and which are now being used to prepare the committee's recommendations for changes in Soil Taxonomy. In this circular letter I will give the bare outlines of these concepts, and also of a number of other proposals submitted to me in writing during and after the sessions. F. Beinroth agreed that this material should be distributed prior to the publication of the Workshop proceedings in order to create the possibility of early testing of the concepts in the field, and to give all the opportunity to react, propose amendments, or after comments on the applicability.

It should be emphasized that we are dealing, as yet, with concepts; the writing of keys and the determination of the ramifications of the recommended changes will take considerable time and much patience. I am working on that but cannot at present give a completion date.

B. Concepts of limits for Kandi taxa*

1. The concept of Kandi taxa in Alfisols and Ultisols is based on the dominance in subsurface horizons of "low activity clays," mainly kaolinite, with or without considerable amounts of free (Fe) oxides in the clay fraction. The Kandi taxa belong to Alfisols and Ultisols, because they have, apart from other properties, an argillic horizon or a clay increase from the surface horizon to a subsurface horizon which from a taxonomic viewpoint can be equated with the presence of an argillic horizon and which is not exclusively due to anisotropy of the parent materials (Soil Taxonomy, p. 26).

Many of the pedons belonging to Kandi taxa have one or more properties that are characteristic for Oxisols, and they may be "mixtures of quartz, kaolin, free oxides, and organic matter," which is the central concept of Oxisols (Soil Taxonomy, p. 323). The boundaries between such Kandi pedons and Oxisols are extremely vague and defy clear taxonomic separation using the present "diagnostic tools" of Soil Taxonomy. Definition of these boundaries was and is one of the key problems to be solved by ICOMLAC.

Other pedons belonging to Kandi taxa have, apart from one or more Oxisol properties, characteristics which are transitional to Inceptisols, e.g. a higher weatherable mineral content than admitted for an oxic horizon, while at the same time having a low or very low clay activity. Definition of the boundary of such pedons with Inceptisols is another of the problems of ICOMLAC.

A third problem which had to be solved when defining the Kandi concept is the boundary between Kandi great groups and those Alfisols-Ultisols which either have a higher activity of the clay or which have another property that, in the keys of Great Soil Groups, is given priority over the Kandi-characteristics (e.g. Plinth and Fragi great groups).

* These concepts were also published in the Proceedings of the Second International Soil Classification Workshop, part II: Thailand (F. Beinroth and S. Panichapong, eds.). Soil Survey Division, Land Development Dept., 1979 (pp. 167-183).

When presenting the proposals which follow in the next three paragraphs, I want to insist on the "taxonomic character" of these proposals. In the first place they are meant to facilitate the task of the field man/soil surveyor making decisions as to which taxon a specific LAC pedon belongs. Less attention had to be given to the pedogenetic uniformity of the Kandi taxi, which range from highly weathered to "not-so-strongly weathered," both with or without weatherable minerals in the 20-200 micron fraction, and from very deep to not-so-deep pedons, etc. The proposed separations are, therefore, pragmatic; they should be tested in the field in order to see if they give separations into compatible groupings.

2. Limits between kandi taxa and Oxisols

The conceptual definition of this limit is: "To distinguish Kandi taxa of Alfisols and Ultisols with a CEC of <16 meq/100 g clay by NH_4OAc at pH 7 in most subhorizons between 20 and 125 cm from Oxisols, the Kandi pedons have one or both of the following:

a. a distinct argillic horizon with at least a moderate grade of blocky structure in the moist soil, having illuviation cutans discernible both in the field and in thin sections in at least 50 cm of any subhorizon at a depth of less than 125 cm, and

b. an epipedon with less than 40 percent clay and an increase in clay within 30 cm to an underlying horizon after mixing of the upper 18 cm, as follows:

--if the epipedon has less than 20 percent clay, the absolute clay increase should be at least 7 percent;

--if the epipedon has 20-40 percent clay, the clay ratio between a subsurface horizon at less than 100 cm and the epipedon should be 1.4."

The following footnotes regarding this concept can be given:

i. The limit of 16 meq/100 g clay (NH_4OAc, pH 7) is not necessarily the limit of all Kandi pedons. In fact for Kandi taxa of Alfisols an upper limit of 24 meq is proposed (see section B.4.). Moreover, the 24 meq limit is proposed for all Kandic subgroups in replacement of the present "oxic" subgroups in Alfisols and Ultisols.

ii. No equivalent ECEC (sum of bases + 1N KCl extractable Al) is, as yet, given here. Tentatively the value of 12 meq seems most appropriate but, because of the pH dependency of the ECEC, a sliding scale may be more appropriate (see this circular letter, section B.4.).

iii. The expression "in most subhorizons between 20 and 125 cm" may be read to mean either that the low CEC horizons should together be more than 52.5 cm $\frac{(125-20 \text{ cm})}{2}$ thick or that the weighed average CEC of all horizons between 20 and 125 cm should be less than 16 meq. Note that the presence of a lithic, paralithic, or petroferric contact is not (yet) taken into account. When the concept is translated in actual definitions and keys this of course has to be done.

iv. The alternatives a. and b. are the core of the proposed concept. While in alternative a. we mention the "argillic horizon," the alternative b. does not speak of an argillic horizon (though there may be one). The background of this concept is well known and has been repeatedly dealt with in various circular letters. The purpose of this proposal is to give a reasonably easy taxonomic tool to the fieldman for making a decision whether or not a low activity clay soil should go with Oxisols. In this respect the concept touches directly on the mandate of ICOMOX and should, therefore, also be tested by that committee.

In the first instance the concept here proposed would not require changes in the definitions and listing of properties of the argillic and oxic horizons, although it might easily accommodate eventual changes. It does, however, require changes in the order definitions of Alfisols (Soil Taxonomy, p. 95, sub 1) and Ultisols (p. 349, sub 1) because a good proportion of pedons falling under b. of the concept may not have an argillic horizon. Such a change in order definition will, of course, have its repercussions on other pages of Soil Taxonomy.

In the first instance the concept proved very useful to make a reasonable separation between new style Oxisols and Kandi taxa of Alfisols and Ultisols in the profiles we studied in Brazil and the Far East.

v. Under a. of this concept the "normal" Kandi Alfisols and Ultisols can be accommodated, i.e. those for which the presence of illuviation cutans is clear. It should be noted that a pedon falling under a. does not have to have a specified clay increase, nor the clay increase in the range now used in the definition of the argillic horizon (p. 27, sub 1). The notion of a "distinct" argillic horizon therefore pertains to the indisputable presence of illuviation cutans.

vi. The requirement under a. for a "moderate grade of blocky structure" may or may not be necessary. It is, however, a reinforcement of the notion of a "normal" Kandi taxon. In fact, the poor visibility of illuviation cutans frequently goes together with a weakly pronounced structure of the argillic horizon.

vii. The depth requirement mentioned under a. of discernible cutans is multipurpose. First it could serve to admit the presence of a subsurface horizon with all properties of an oxic horizon overlying an argillic horizon. This would circumvent the problem we have had with the so-called "thin oxic horizon." Secondly it may serve to leave in Oxisols certain uniformly fine-textured Oxisol pedons in which, under certain circumstances, a thin argillic horizon has formed. However, this has to be tested by ICOMOX.

viii. Pedons which fall under b. are distinguishable on their clay increase only; they may or may not have clear illuviation cutans as specified under a. Specifically this concept is introduced to accommodate those pedons with a clear clay increase ("textural B"), but which do not show clear illuviation cutans in field and/or thin section examination. The clay increase required is nearly commensurate with proposals by G. Smith (circular letter no. 3, pp. 19-21) and by J. Bennema and J. Comerma (circular letter no. 8, appendix 5, circular letter no. 9, pp. 98 and 99). Pedons which have more than 40 percent clay in the epidedon and which do not show distinct illuviation cutans as specified under a. will fall "automatically" in Oxisols, provided the additional requirements for an oxic horizon are present.

ix. There is no decision, as yet, on using 40 percent clay as a limit to exclude pedons from b. or 35 percent as is done for the particle size classes at the family level. It should be noted that family particle size classes do not pertain specifically to an epipedon. Either limit could serve, but please let me know your preference.

Because we are working mostly with poorly dispersible clays, an alternative limit of 2.5 times water retained at 15 bars tension may have to be introduced in keys and definitions (see Soil Taxonomy, footnote 2, p. 325). Note that the 40 percent clay limit would be equated with 16 percent water at 15 bars tension and the 35 percent clay limit with 14 percent water.

x. The requirement that the clay increase should occur within 30 cm is introduced to exclude soils (quite common) having a very gradual clay increase.

xi. The requirement to mix the upper 18 cm of the epipedon was made to exclude soils with a very thin coarser textured upper part of the epipedon. Originally a depth of 20 cm was proposed, but, since the "18 cm mixing requirement" is used elsewhere in Soil Taxonomy (Mollisols, Vertisols, p. 92) it was used here as well.

xii. Schargel proposed that clay increase in pedons as defined under b. in the concept should be limited to a maximum depth, as follows:

--if the epipedon has 20-40 percent clay, the clay increase should occur at less than 100 cm; (This limit has been introduced already in the conceptual definition.) and

--if the epipedon has less than 20 percent clay, but does not meet the requirements of a grossarenic subgroup, the clay increase should occur at less than 125 cm; and finally

--if the epipedon meets the requirements for a grossarenic subgroup, the clay increase should occur between 100 and 200 cm.

It should be noted that no specific solution is given for pedons where the clay increase is due partly or completely to stratification and lithological discontinuities. This problem, which as I have found is still under lively discussion in the U.S. Soil Survey, will remain with us, unchanged by the concept definition of kandi.

xiii. I am sure that many more footnotes will be forthcoming regarding the conceptual definitions. So be it, but let me, for your elucidation and moral support, quote the following from Charles E. Kellogg's "A Lament for B" (1957, privately printed at the Twelve Oaks Press):

"The old podzolic texture B
Has clay skins now to make it B
And if there are no skins to see
it still may be a clayey B."

3. Limits between Kandi taxa and Inceptisols

These limits were not extensively discussed at the Brazil and S.E. Asia workshops, nor have they received much attention in the circular letters. Border-line cases are either less frequent, or the limits are easier to determine, or both. In various private discussions and letters, however, the problem was raised; hence this paragraph.

In fact there are two kinds of border-line cases, partially overlapping, as follow:

--pedons which have a CEC/100 g clay (NH_4OAc-pH 7) between 16 and 24 meq; and

--pedons which have a CEC/100 g clay of less than 16 meq, but which are excluded from Oxisols because of the presence of weatherable minerals (more than 3 percent in the 20-200 micron fraction, or more than 6 percent if occluded by iron, of Soil Taxonomy, p. 38, 2nd column, and footnote 13).

As in the case of transitions between Kandi pedons and Oxisols, we do have border-line cases with Inceptisols where we run into trouble in the determination of whether or not there is an argillic horizon.

Hence, I offer tentatively as a working concept: To distinguish kandi taxa of Alfisols and Ultisols with a CEC between 16 and 24 meq/100 g clay (NH_4OAc-pH 7) or with a CEC of <16 meq and a weatherable mineral content of more than 3 percent between 20 and 200 microns from Inceptisols, the Kandi pedons have one or both of the following:

a. an argillic horizon, having illuviation cutans discernible both in the field and in thin sections, and

b. a clay increase within 30 cm from an epipedon to an underlying horizon after mixing of the upper 18 cm, as follows:

   --if the epipedon has less than 15 percent clay, the absolute clay increase should be at least 3 percent;

   --if the epipedon has more than 15 percent, but less than 40 percent clay, the clay ratio between a subsurface horizon to that of the epipedon should be >1.2;

   --if the epipedon has more than 40 percent clay, the absolute clay increase should be at least 8 percent.

It should be noted that this conceptual definition of limits is not completely parallel to the one under paragraph B.2. No depth requirements are given under a. which is in line with present taxonomy where no cambic horizon is recognized as such if there is an argillic horizon. Also, under b. the clay increase rules are used as they stand on p. 27 of Soil Taxonomy, however, without mentioning the presence of eluvial or illuvial horizons. In my present collection of pedons there are only one or possibly two that are affected by this conceptual definition, not enough, in my belief, to support the proposal.

Note: In the definitive write-up of this paragraph for the Proceedings of the Second International Soil Classification Workshop this working concept was dropped, since it is incompatible with the conceptual definition developed in paragraph B.2. of this letter.

4. Limits between Kandi taxa and high activity clay (HAC) Alfisols and Ultisols

In correspondence, in several circular letters, and during both the Brazil and S.E. Asia meetings, this subject has been discussed extensively. The diagnostic "key property" has been, and still is, the CEC by NH_4OAc at pH 7, in meq/100 g clay. The diagnostic depth was proposed to be the upper 50 cm of the argillic horizon, the weighed average CEC to be determinant. In principle, we should add to this depth requirement the weighed average CEC of the upper 50 cm of the subsurface horizon that replaced the argillic horizon in the conceptual definitions, sub b., of paragraphs B.2 and B.3 of this letter.

The diagnostic limits of CEC now recommended, are as follows:

--Between Kandi great groups of Ultisols and HAC Ultisol taxa: 16 meq/100 g clay (NH_4OAc), as specified above for depth.

--Between Kandi great groups of Alfisols and HAC Alfisol taxa: 24 meq/100 g clay (NH_4OAc), as specified above for depth.

--For Kandic subgroups in relevant taxa of Alfisols and Ultisols: a maximum of 24 meq/100 g clay (NH_4OAc), as specified above for depth.

Depending on the place which the Kandi great groups ultimately are given in the key Kandic subgroups will occur in various great groups. Two examples may serve here:

In Ustalfs, provided the Kandi great groups key out (Soil Taxonomy, p. 138) after HCC, Natrustalfs, we may expect a Kandic subgroup in HCB (Plinthustalf). The introduction of Kandic subgroups in HCA (Durustalfs), and HCC (Natrustalfs) appears redundant.

In the Udults (Soil Taxonomy, p. 360), all of the present great groups may have kandic subgroups except, of course, the Kandi great groups (if they are introduced). If the Kandi great groups key out after FCB (Plinthudults), this great group and also FCA (Fragiudults) may have Kandic subgroups throughout the whole range of CEC values less than 24 meq/100 g clay.

However, on the contrary, the Kandic subgroups of FCC (Paleudults), FCD (Rhodudults), FCE (Tropudults) and FCF (Hapludults) (may) have Kandic subgroups where the diagnostic CEC value is confined by 16 and 24 meq/100 g clay.

The examples given may serve as an indication of the repercussions which our efforts are going to have on other taxa; as I said before, rewriting the keys is not something that can be quickly done!

The use of ECEC (sum of bases plus 1N KCl extractable Al) as an additional or alternative diagnostic property has been discussed extensively. For the Kandi taxa in Ultisols there is a consensus that 12 meq/100 g clay should serve as an alternative diagnostic limit as follows:
... have a CEC (NH_4OAc-pH 7) of <16 meq or an ECEC of <12 meq clay in most subhorizons ....

In view, however, of the dominance of the pH dependent charge in low activity clays, the use of ECEC as a diagnostic property is difficult. For the kandi taxa in Alfisols, using the ratio 16:12 between the two CEC values, the diagnostic ECEC would become 18 meq. Sufficient data are not available to either confirm or reject this value. A "sliding" diagnostic ECEC limit depending on pH may be required but more work is needed to be certain.

ICOMLAC is well aware that the diagnostic limits, based on CEC values calculated on 100 g clay, are subject to the several sources of errors that have been discussed both in the circular letters and during the Brazil and S.E. Asia meetings. More work is required on these and alternative determinations, including quantitative or semi-quantitative determinations of the mineralogical composition of the clay fraction. Much is known, but it still has to be "translated" into taxonomic terms, requiring the continuing and concerted efforts of soil chemists/mineralogists and soil taxonomists.

C. Kandi great groups

1. Separation of two great groups according to depth

The original trend in defining the typic representative pedons of the Kandi taxa was that they should have an attenuated transition between B and C horizons. In common with the "Pale" great groups of Ultisols, they would have a textural profile such that the clay content would not diminish from its maximum with 20 percent or more at a depth of 150 cm, or (clear) clay cutans should be present at that depth. Thinner pedons would fall in leptic, lithic, paralithic or petroferric subgroups. Against this trend, two objections were made:

--In certain regions (e.g. Malaysia) virtually all of the better drained Ultisols would fall under one great group, that of the Kandiudults. This was deemed undesirable from a geographic and, possibly, a soil management point of view.

--By keeping the deep and shallower Kandi subgroups together in one great group a proliferation of subgroups, frequently with double or triple names, would occur.

Added to this the "lumping" of Kandi pedons, irrespective of their depth, would require considerable regrouping of Paleudults and Hapludults with LAC in the Southeast of the United States, and thus would be even less acceptable.

Basically, therefore, two Kandi great groups are to be distinguished in most suborders of Alfisols and Ultisols, as follows:

--Kandi great groups: "... have a clay distribution such that the percentage of clay does not decrease from its maximum amount by more than 20 percent of that maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum has skeletans on ped faces or has 5 percent or more plinthite by volume."

--Kanhaplo great groups: "... have a clay distribution such that the percentage of clay decreases from its maximum amount by more than 20 percent of that maximum within 1.5 m of the soil surface and have no skeletans on ped faces at 1.5 m depth, or have a lithic, paralithic, or petroferric contact within 1.5 m of the soil surface."

The following footnotes should be made:

i. The above definitions are conceptual; they are not definitions to be used as such in the keys.

ii. The depth criteria of the Kandi great groups follow those of the Pale great groups of Ultisols in most respects, but differ from them in not requiring the percentage of weatherable minerals in the 20-200 micron fraction in the upper 50 cm of the argillic horizon (or its "equivalent") to be less than 10. This will be dealt with under paragraph C.2. of this letter.

iii. The depth criteria of the Kandi great groups follow those of Paleudalfs, Paleustalfs, and Palexeralfs, but the remaining criteria differ from these great groups in all other aspects mentioned in Soil Taxonomy (keys, pp. 125, 138, and 147). The definition of Paleboralfs is irrelevant in this respect; it may moreover be expected that Kandi taxa in Boralfs are redundant. Aqualfs have at present no Pale great group, but it appears probable that Kandi taxa should be foreseen.

iv. The introduction of both the Kandi and the Kanhaplo great groups in Aqualfs and Aquults should be queried. In those suborders it appears that the thickness of the "clay bulge" loses much of its taxonomic and management importance. Hence, in these two taxa, a single great group (Kandi) may suffice, whereby distinctions between deep and shallow pedons are relegated to subgroup level.

2. <u>Weatherable minerals</u>

For the present Pale great groups of Ultisols the lack of weatherable minerals in the 20-200 micron fraction (less than 10 percent in the upper 50 cm) is one of the diagnostic properties. Discussions on this topic have resulted in omitting this property as diagnostic for Kandi taxa in Ultisols. For Alfisols the weatherable mineral content was never a diagnostic property at great group level, hence the Pale great groups of Alfisols are not required to have a low content in weatherable minerals. The basic reason to drop any mention of weatherable minerals from the "Kandi concept" is that there is no good correlation between the dominance of low activity clays and the absence or presence of weatherable minerals in the 20-200 micron fraction. While it is true that among Kandi pedons in Ultisols most have a low content of weatherable minerals, there are important exceptions which tend to occur in well defined geographic patterns, dependent mainly on origin of soil forming materials. For instance, among Kandiudults and Kanhapludults in S. Nigeria, those formed on materials derived from intermediate crystalline rocks mostly have over 10 percent weatherable minerals at the specified depth. On the other hand, not all Kandi pedons of Alfisols have a high content of weatherable minerals as can be seen in Kandiustalf pedons on old sediments along the coast of W. Nigeria, Benin, and Togo. These examples were confirmed during the S.E. Asian workshop by others from such locales as Venezuela. Content of weatherable minerals in Kandi taxa of Alfisols and Ultisols would, therefore, be relegated to the subgroup level (see section D.).

3. <u>The "Trop" great groups, and their relation to Kandi taxa</u>

The question was raised (by G. Smith) if, under these circumstances, the "Trop" great groups in Alfisols and Ultisols would still remain relevant. These are the following:

--for Alfisols: Tropaqualfs and Tropudalfs;

--for Ultisols: Tropaquults, Tropohumults, and Tropudults.

The following tentative review could be given, based on the assumption that Kandi and Kanhaplo great groups would be keyed out before Trop great groups.

--Tropaqualfs: LAC pedons would be excluded from this taxon, the others remain. In my experience many of the present Tropaqualfs are dominated by high activity clays, while a minority would go to Kandi taxa.

--Tropudalfs: This already rare taxon would diminish in importance because LAC pedons would be excluded. There will remain, however, Tropudalfs, e.g. those on relatively young materials derived from basic volcanic rocks. The most extensive areas I have seen were on Luzon, in the Philippines, and they would remain in this taxon.

--Tropaquults: This great group, already rarely found (Soil Taxonomy, p. 355), will undoubtedly diminish in importance when Kandi taxa are introduced. They would be limited to Aquults which, apart from the temperature regime requirement, would have to be dominated by "high activity clays" and which should not have properties diagnostic for the "Pale" great group (Soil Taxonomy, p. 351). Personally I do not know of such pedons, and this taxon may well be redundant.

--Tropohumults: Interpreting the section of Soil Taxonomy dealing with Tropohumults (Soil Taxonomy, pp. 358-360), one might conclude that high activity clay pedons are common in this taxon. However, it is possible that for the most part the higher CEC in these pedons is determined by the high content of O.M., while, at the same time, the clay activity may be low. The Tropohumults that I personally have seen outside of Hawaii would all cease to be Tropohumults, as they are all dominated by low activity clays.

--Tropudults: There is no doubt that the introduction of Kandi taxa will diminish the importance (already doubtful) of this great group considerably, but interpretation of the data given in Soil Taxonomy (pp. 367-369) would indicate that they do exist, even if the low activity clays are excluded.

In conclusion (of this paragraph): ICOMLAC, within its present mandate, could not propose to "do away" with the Trop taxa on the basis of redundancy.

4. "Plinth" great groups

The Malaysian-Thai workshop did not give a definite view on the relevancy and placing of Plinth great groups. Hence, ICOMLAC will leave the definitions and placing in the keys of these great groups as they now are in

Soil Taxonomy. Kandi and Kanhaplo great groups would key out after the Plinth great groups, and low activity clays in the latter would be distinguished on the subgroup level (Kandic subgroup).

D. Subgroups of Kandi taxa

During the Malaysian-Thai workshop attention to subgroups was given mainly during the field tours. As the records of the discussions are not to date in my possession only a few remarks can be given of the subgroups discussed during the workshop.

--the Allic subgroups of Kandi taxa in Ultisols. In continuation of discussions during the Brazil workshop, the Allic subgroup was again discussed. The key question, i.e. the depth at which high Al^{3+} saturation should be diagnostic, was not resolved. It was therefore tentatively decided not to introduce an Allic subgroup. The chemist/mineralogists, specifically G. Uehara, point out that possibly the Al^{3+} saturation is less important than the nature and amounts of other adsorbed cations. When defining both Allic and, eventually, Acric subgroups this parameter should be taken into account. More specifically a lack of adsorbed Ca^{2+} may be of more importance than a concomittant high Al^{3+} saturation. As an example pedon No. 11 from Thailand (Phangnga series) was cited, where extractable Ca is well below 0.1 meq in most of the B_{2t} horizon. Further information on relevant diagnostic values was promised by Uehara.

--The Acric subgroups in Kandi taxa of Ultisols. The proposed diagnostic ECEC boundary for this eventual subgroup is (less than) 2.5 meq/100 g clay. Again, however, as in the case of the Allic subgroup (now defunct), the lack of cations, in particular Ca^{2+}, may be more important than the ECEC value per se. This too is a subject to be pursued further.

--The Vadic subgroup (connotation: vadose water; vadosus (L) = shallow; vadum = a shallow or ford).

A subgroup is desired for such pedons which are not hydromorphic enough to be considered as an Aquic subgroup but which show moderate to strong iron segregation, frequently due to interflow-water saturation during part of the year. The pedons which were called "ferric" in the Brazil meeting, and at least two pedons in Thailand (Nos. 11, Phangnga, and 18, Ban Bung series) have similar characteristics. This subgroup should be distinguished from the Typic subgroups on the basis of distinct (rusty) mottling at less than 100 cm depth.

--Subgroups for pedons respectively rich and poor in weatherable minerals.

As was discussed above, the content of weatherable minerals in the 20-200 micron fraction in Kandi and Kanhaplo great groups would not be used as a diagnostic characteristic at this level. From my own experience it appears that this content, especially of minerals that provide nutrient elements upon weathering, is important from a soil management point of view both in Ultisols and Alfisols. Moreover since it is in most cases related to composition and age of the soil forming material, there appear to be a sound geographical basis for making the distinction between "rich and poor" in weatherable minerals.

This characteristic cannot be relegated to the family level since the mineralogical composition of the 20-200 micron fraction is not used as a criterion in the clayey and clayey-skeletal families. Hence, it appears opportune to introduce "rich" and/or "poor" distinctions at the subgroups level.

In this respect a note from R. Schargel is relevant and his proposal should be tested:

"To separate Kandi and Kanhaplo pedons as regards their content of weatherable minerals, the 1.5 percent K_2O content in the fine earth (less than 2 mm) might be used (tested) as a limit. Possibly, the sum of K_2O, CaO, MgO, and Na_2O gives a better separation, also at 1.5 percent or at a relatively higher percentage. The first 50 cm of the argillic horizon (or equivalent finer textured horizon) would be diagnostic in this respect."

Schargel adds as justification that it is easier for most laboratories to get the total elemental analysis than the mineralogical data. For Venezuela, the 1.5 percent K_2O seems to work well, but the critical K_2O content might be as low as 1 percent. I think that this alternative limit certainly is worth being tested.

Nomenclature-wise I would suggest that the characteristic "less than 10 percent weatherable minerals in the 20-200 micron fraction" should be included in the list of properties of all Typic subgroups. The pedons with more than 10 percent weatherable minerals would require a separate subgroup for which we may use "caric" (carus (L) = rich; the mnemonicon should be "cher," for those who have not forgotten all their French).

Circular Letter No. 11, February 1979

In this circular letter I primarily wish to introduce two items in appendix form. This is so that you may more conveniently use these proposals separately from the collection of circular letters for field testing.

Appendix 1 deals with a definition of a "finer textured subsurface horizon" as a diagnostic horizon, which would be placed under the heading "other diagnostic soil characteristics," Soil Taxonomy, p. 16.

In the alphabetic order of such characteristics it should be placed between durinodes and gilgai. This proposal, somewhat amended, is from S. Buol. The maximum depth limit at which a "finer textured subsurface horizon" should be recognized as diagnostic is based on the proposal of R. Schargel, circular letter no. 10, page 116, sub xii.

The introduction of a diagnostic "finer textured subsurface horizon" does considerably enlighten the task of writing the key and definitions of the Kandi taxa. In appendix 2, therefore, this Buol brainwave (BB for short) is used. Let me quote a pertinent section of Buol's letter, especially for our ICOMOX colleagues.

> Assuming you will see the brilliance of my proposal I will point out some other possible uses of such a criteria in Soil Taxonomy. If we allow the >40 percent clay surface rule to expand Oxisols, those new Oxisols with a "finer textured subsurface horizon" could be the "Argi" great group without the clay skin problem. We would probably want to exclude moderate or stronger grades of blocky structure from the Oxisols. However, I am second guessing the group on this point. Also, if some people would be so bold as allow clay content increase with depth to determine classification, rather than the genetic concept of argillic, we could put this in Alfisols, Ultisols, Argiaquolls, and Argiudolls to eliminate some of the Inceptisols vs. Ultisol and Alfisol problem as it presently is defined. When backed to the wall on this idea of a finer textured subsoil, regardless of genetic implications, I guess I would use the argument that Soil Taxonomy is a morphogenetic system with morphology taking precedence when we are unable to agree or determine the genetic pathways with our present technology.

You will agree that Buol's list of implications is far reaching. As regards ICOMLAC, I would not want to go quite that far and fast; the use of a diagnostic "finer textured subsurface horizon" should, in my opinion, be limited to the terrain or competence of ICOMOX and ICOMLAC, at least for the time being. The argillic horizon, as presently defined in Soil Taxonomy, should take precedence in the diagnosis of the taxon, and the "finer textured subsurface horizon" should only be used where the argillic horizon is not clearly expressed. The two partly overlap, but not all argillic horizons can be counted as "finer textured subsurface horizons," nor, for that matter, are all finer textured subsurface horizons to be considered as argillic within the present genetic concept and definition of Soil Taxonomy.

Appendix 2 contains the draft keys to great groups of Kandi and Kanhaplo taxa, with footnotes. In the elaboration of this key I have paid due attention to correspondence received after the S.E. Asia meeting and to comments pertaining to circular letter no. 10. A first version of this key was sent to some of you and was also discussed during an informal ICOMOX meeting in Ghent, Belgium in December. Several comments from that meeting are incorporated in this version, including the corrections proposed by G. Smith.

While elaborating the draft keys I found that the concepts and concept definitions of circular letter no. 10 could not be followed to the letter. Two major and a few minor changes of the original concepts had to be made. The major changes are as follow:

--Section B.3., p. 112, concerns the limits between Kandi taxa and Inceptisols. In the working concept, sub b., other clay increase rules are proposed than were used to determine limits between Kandi taxa and Oxisols (section B.2., p. 108 sub b.). In practice this would lead to a very complicated definition of most taxa in the keys, therefore this distinction was dropped and replaced by the "finer textured subsurface horizon" as defined in appendix 1 of this letter.

--Section B.4., p. 113, concerns the limits between Kandi taxa and high activity clay (HAC) Alfisols and Ultisols. In this proposal the diagnostic CEC (pH 7) limit for Kandi great groups of Ultisols is set at <16 meq/100 g clay, while for the Kandic subgroups this limit would be <24 meq/100 g clay. This would lead to a number of Kandic subgroups of Paleudults, Rhodudults, Tropudults, and Hapludults. In practice such subgroups would be difficult to handle because the CEC is such a 'finagly' characteristic in the first place. S. Buol proposes, and I am taking over his proposal, to use the 16 meq limit "across the board," hence requiring the Kandic subgroups in Ultisols also to have <16 meq CEC (by NH_4OAc at pH 7). Buol suggests that, if it is felt necessary, one could leave the oxic subgroups to define the 16-24 meq range.

Appendix 1 to Circular Letter No. 11
(Contribution of S. W. Buol and F. R. Moorman)

Proposed definition of a "finer textured subsurface horizon", to be included in Soil Taxonomy under the heading "Other Diagnostic Soil Characteristics" (p. 46) and to be placed alphabetically on p. 48 between durinodes and gilgai.

Finer Textured Subsurface Horizon (FTSH)

Many soils have subsoil clay contents greater than in their surface horizons. Many such soils are recognized as having argillic or natric diagnostic horizons. However, there are many soils where the genetic processes for forming a higher clay content in the subsoil cannot be agreed upon by pedologists. Clay skins are not readily evident to indicate formation by the lessivage process. Several alternative processes may create this morphological feature. It is possible that clay in the surface horizon may have been removed from the soil by erosion. Certainly much of the clay in the subsoil has been formed *in situ* from weathering by larger sized primary minerals. Also it is possible that in many soils, especially those formed in transported materials, that while textural lithologic discontinuities may be present between the topsoil and the subsoil, the evidence for such discontinuities is extremely difficult to establish because of extensive weathering and other pedogenic processes. While it is not desirable to include in this definition finer subsoil textures that are clearly the result of fluvial activity, as evidenced by platy structure or irregular organic matter contents with depth, it may include subsurface horizons where a fluvial origin is suspected providing the horizon has granular, single grain, or blocky structure, or is massive or structureless. While these features can be determined from the examination of an individual pedon, it is often prudent to examine several pedons in similar geomorphic settings to determine the lateral continuity of finer textured subsoil horizons.

Specific diagnostic limits of a finer textured subsurface horizon (FTSH) have to include rate of clay increase with depth, absolute depth in the solum at which the clay increase takes place, and absolute amount of clay increase:

--Rate of clay increase: The maximum vertical distance within which a diagnostic clay increase from the coarser overlying layers or horizons to a finer textured horizon takes place is set at 30 cm. This will exclude from the definition of a finer textured subsurface horizon those cases where the clay increase, though sufficiently large as defined below, is diffuse.

--Depth of clay increase: It is common to find very thin surface horizons that have lost clay, for instance by erosion, and such layers are easily destroyed by cultivation practices such as plowing (whereby the vertical texture differentiation between the surface horizon and the underlying horizons disappears). To exclude such cases from the present definition the upper soil should be mixed to a depth of 18 cm for the determination of its clay content. This sets the minimum depth at which the clay increase to a finer textured subsurface horizon is diagnostic at >18 cm. In practice comparisons are usually of 1) the mixed sample of the top 18 cm and 2) the sample at a depth from the surface of 43-48 cm.

By convention, the maximum allowable depth of a diagnostic clay increase is made to depend on the clay content and particle size class of the overlying layers or horizons, as follows:

1. If the clay content is 20 percent or more, the upper boundary of the FTSH should occur at less than 100 cm from the surface.
2. If the clay content is less than 20 percent, and the particle size class of part or all of the upper 100 cm is finer than sandy or sandy skeletal, the clay increase should occur at less than 125 cm from the surface.
3. If the particle size class of the upper 100 cm is sandy or sandy skeletal (the texture is sand or loamy sand), the clay increase should occur between 100 and 200 cm from the surface in the major part of the pedon.

Amount of clay increase:

1. If any part of the overlying horizons or layers has ≤20 percent total clay in the fine earth fraction, the finer textured subsurface horizon must contain at least 7 percent more clay.

2. If the overlying horizons or layers have >20 percent and ≤40 percent total clay in the fine earth fraction, the ratio of clay in the finer textured subsurface horizon to that of the overlying horizon(s) or layers must be 1.4 or more.
3. If the ovelying horizons or layers have >40 percent total clay in the fine earth fraction, the finer textured subsurface horizon must contain at least 16 percent more clay.

Thickness: The thickness requirements of the finer textured subsurface horizon are those of the argillic horizon (Soil Taxonomy, p. 27, sub 2).

Keys to great groups of suborders which include Kandi- and Kanhaplo taxa alfisols

HA. AQUALFS (Soil Taxonomy, p. 109)

1) HAA. -----------Plinthaqualfs

HAB. -----------Natraqualfs

HAC. -----------Duraqualfs

2) HAD. Other Aqualfs that have <24 meq CEC/100 g clay (by NH_4OAc) or

3) have <18 meq ECEC/100 g clay in either or both

a. The weighted average of the upper 50 cm of an argillic horizon;

b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kandiaqualfs

HAE. -----------Tropaqualfs

4) HAF. -----------Fragiaqualfs

4) HAG. -----------Glossaqualfs

4) HAH. -----------Albaqualfs

HAI. -----------Umbraqualfs

HAJ. -----------Ochraqualfs

Notes for Aqualfs:

1) In Plinthaqualfs and Natraqualfs a Kandic subgroup has to be introduced, which will require an additional item on the definition of the Typic subgroup.
2) LAC Aqualfs may be rare. This is the reason that in the present proposal no distinction is made between a "Kandi" and a "Kanhaplo" taxon. If required a Kanhaplo great group should be introduced but, conceivably, a diminished clay content may be indicated at the subgroup level (Leptic). Note that at present for this suborder, no "Pale" great group is foreseen in Soil Taxonomy. Moreover, no "Oxic" subgroup occurs in any of the present great groups.
3) ECEC is the sum of bases plus 1N KCl extractable Al expressed as Al^{3+}.
4) LAC pedons with the characteristics of the HAF, HAG, and HAH great groups may exist. Such pedons would be Fragic, Glossic, and Albic subgroups of Kandiaqualfs.

HC. USTALFS (Soil Taxonomy, p. 138)

HCA. -----------Durustalfs

1) HCB. -----------Plinthustalfs

HCC. -----------Natrustalfs

HCD. Other Ustalfs that meet both of the following requirements:

2) 1. Do not have a lithic, paralithic, or petroferric contact within 1.5 m of the surface and either have a lithoplinthic horizon within 1.5 m of the surface or have a clay distribution such that the percentage of clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, and

2. have <24 meq CEC/100 g clay (by NH_4OAc) or have <18 meq ECEC/100 g clay in either or both:

a. The weighted average of the upper 50 cm of an argillic horizon;

b. The weighted average of the upper 50 cm of a finer textured subsurface horizon and the surface horizon has <40 percent clay.

Kandiustalfs

HCE. Other Ustalfs that have <24/per 100 g clay (by NH_4OAc) or have <18 meq ECEC/100 g clay in either or both:

a. the weighted average of the upper 50 cm of an argillic horizon;

3) b. the weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kanhaplustalfs

4) HCF. -----------Paleustalfs

4) HCG. -----------Rhodustalfs

4) HCH. -----------Haplustalfs

Notes for Ustalfs:

1) A Kandic subgroup is required in Plinthustalfs, possibly in Natrustalfs.
2) In this definition, the section sub 1 is based on the definition of the present Paleustalfs; however, with several differences:
   a. The requirement that the clay distribution pertains to the argillic horizon (official revision of the 1975 text) is not adopted here because at least part of the "finer textured subsurface horizons" cannot be defined as argillic horizons according to the present text of Soil Taxonomy.
   b. Contrary to what is defined for Paleustalfs (p. 142, definition sub 3 b(1)), a clay decrease of more than 20 percent from the maximum always excludes the pedons from Kandiustalfs, irrespective if there

>5 percent plinthite by volume or if there are skeletans or other evidences of clay movement.

c. The color requirement for Paleustalfs (p. 142, definition sub 3 b(2)) is not adopted for Kandiustalfs.

d. The alternate diagnostic characteristics of Paleustalfs, i.e. presence of a petrocalcic horizon (p. 142, definition sub 3 a) and the abrupt transition to an argillic horizon (p. 142, definition sub 3 c) are not adopted for Kandiustalfs.

3) This wording may be ambiguous in cases where the "finer textured horizons" are less than 50 cm thick. If this occurs an alternate definition may be required.

4) The present "Oxic" subgroups of HCF (Paleustalfs), HCG (Rhodustalfs), and HCH (Haplustalfs) will become redundant; no Kandic subgroups occur in HCF, HCG, and HCH. There will be a Rhodic subgroup in both the Kandiustalfs and the Kanhaplustalfs.

1) HE. UDALFS (Soil Taxonomy, p. 125)

HEA. -----------Agrudalfs

HEB. -----------Natrudalfs

HEC. -----------Ferrudalfs

2) HED. -----------Glossudalfs

2) HEE. -----------Fraglossudalfs

2) HEF. -----------Fragiudalfs

3) HEG. Other Udalfs that meet both of the following requirements:

1. Do not have a lithic, paralithic, or petroferric contact within
4) 1.5 m of the surface and have a clay distribution such that the percentage of clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, and

2. Have <24 meq CEC/100 g clay (by NH_4OAc) or have <18 meq ECEC/100 g clay in either or both

   a. The weighted average of the upper 50 cm of an argillic horizon;

   b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kandiudalfs

HEH. Other Udalfs that have <24 meq CEC/100 g clay (by NH_4OAc) or have <18 meq ECEC/100 g clay in either or both:

a. The weighted average of the upper 50 cm of an argillic horizon;

5) b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kanhapludalfs

HEI. -----------Paleudalfs

HEJ. -----------Rhodudalfs

6) HEK. -----------Tropudalfs

HEL. -----------Hapludalfs

Notes for Udalfs:

1) No Plinth great group is, at present, foreseen in the Udalf suborder. If required Plinthudalfs would fit between HEA and HEB. A Kandic subgroup may be necessary in this taxon.
2) The great groups HED, HEE, HEF may require Kandic subgroups, though no "Oxic" subgroups are foreseen in the present text of Soil Taxonomy.
3) The notes in margin, No. 2 for Ustalfs are also valid for the proposed HEG- Kandiudalfs.
4) In the key definition sub 1. of HEG, no mention is made of a lithoplinthic horizon as was done for HCD (Kandiustalfs). This addition may be necessary if Kandiudalf pedons with a lithoplinthic horizon are found.
5) This wording may be ambiguous in cases, where the "finer textured horizons" are less than 50 cm thick. If this occurs an alternate definition may be required.
6) The present "Oxic" subgroup of HEC (Tropudalfs), will become redundant.

ULTISOLS

FA. AQUULTS (Soil Taxonomy, p. 351)

1) FAA. -----------Plinthaquults

2) FAB. -----------Fragiaquults

2) FAC. -----------Albaquults

FAD. Other Aquults that meet both of the following requirements:

1. do not have a lithic, paralithic, or petroferric contact within 1.5 m of the surface and either have a lithoplinthic horizon within 1.5 m of the surface or have a clay distribution such that the percentage of clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, and
2. have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:

a. The weighted average of the upper 50 cm of an argillic horizon;

b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kandiaquults

3) FAE. Other Aquults that have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:

a. The weighted average of the upper 50 cm of an argillic horizon;

b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kanhaplaquults

4) FAF. -----------Paleaquults

4) FAG. -----------Tropaquults

4) FAH. -----------Ochraquults

Notes for Aquults:

1) Kandic subgroups will be required for FAA (Plinthaquults), FAB (Fragiaquults), and FAC (Albaquults). The present Oxic Plinthaquults would become Kandic if the diagnostic CEC (by NH_4OAc at pH 7) is less than 16 meq/100 g clay. The remainder of the Oxic taxa would be maintained as such.
2) It should be noted that the ranking of Fragiaquults and Albaquults is prior to the Kandi taxa in Aquults. This ranking is different from what we used in Aqualfs. The reason is that in the present proposal, the Kandi taxa key out immediately before the Pale taxa, or in the case of Aqualfs, before the Tropaqualfs. The Soil Taxonomy ranking within the suborder of Aqualfs differs from that within most other suborders, and this difference remains in the present proposals.
3) Contrary to what is proposed for the Aqualf suborder, a "Kanhaplo" great group is foreseen in the Aquults suborder. This distinction is in line with the present key, where deep ("Pale") profiles are recognized at the great group level.
4) No Kandic subgroups exist in the great groups: FAF (Palequults), FAG (Tropaquults), FAH (Ochraquults), and FAI (Umbraquults). Provisionally, Oxic subgroups would remain to accommodate pedons with a CEC/100 g clay (by NH_4OAc) between 16 and 24 meq, at the appropriate depth. At present, no "Oxic" subgroups are indicated in Soil Taxonomy for these great groups.

FB. HUMULTS (Soil Taxonomy, p. 355)

1) FBA. -----------Sombrihumults

2) FBB. -----------Plinthohumults

FBC. Other Humults that meet both of the following requirements:

1. Do not have a lithic, paralithic or petroferric contact within 1.5 m of the surface and either have a lithoplinthic horizon within 1.5 m of the surface or have a clay distribution such that the percentage of clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, and

3) 2. Have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:

   a. The weighted average of the upper 50 cm of an argillic horizon;

   b. The weighted average of the upper 50 cm of a finer textured subsurface and the surface horizon has <40 percent clay.

   Kandihumults

FBD. Other Humults that have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:

a. The weighted average of the upper 50 cm of an argillic horizon;

b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

   Kanhaplohumults

4) FBE. -----------Palehumults

4) FBF. -----------Tropohumults

4) FBG. -----------Haplohumults

Notes for Humults:

1) In this great group (Soil Taxonomy, p. 358), no subgroups were developed, but a Humoxic and an Orthoxic subgroup are proposed, diagnosed by the soil temperature regime. It may be indicated to replace both subgroups by one single subgroup, based on <16 meq CEC/100 g clay (by NH_4OAc) or <12 meq ECEC/100 g clay at the appropriate depth. The temperature regime would be relegated to the family level.
2) At present (p. 356), Plinthohumults key out after Palehumults, contrary to the ranking in all other suborders of Alfisols and Ultisols. Because a change in ranking would not have easily detectable consequences (subgroups of Plinthohumults are not yet developed), it is proposed in the present key to rank Plinthohumults before Kandihumults, Kanhaplohumults, and Palehumults. A Kandic subgroup of Plinthohumults would be defined as having <16 meq CEC/100 g clay (by NH_4OAc) or <12 meq ECEC/100 g clay at the appropriate depth.
3) The CEC is determined on total fine earth, including organic matter. Correction for organic matter is as yet under discussion, and no agreement in this respect has been reached.

4) At present one Oxic subgroup (Orthoxic) exists in FBE (Palehumults), and three (Humoxic, Orthoxic, Ustoxic) in FBF (Tropohumults). No Oxic subgroup is recognized in FBG (Haplohumults). In the present draft, only those pedons with a CEC/100 g clay (by NH_4OAc) between 16 and 24 meq would remain in the aforementioned Oxic subgroups.

1) FC. UDULTS (*Soil Taxonomy*, p. 360)

2) FCA. -----------Fragiudults

2) FCB. -----------Plinthudults

FCC. Other Udults that meet both of the following requirements:

1. Do not have a lithic, paralithic, or petroferric contact within 1.5 m of the surface and either have a lithoplinthic horizon within 1.5 m of the surface or have a clay distribution such that the percentage clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, and
2. Have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:
   a. The weighted average of the upper 50 cm of an argillic horizon;
   b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kandiudults

FCD. Other Udults that have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:

a. The weighted average of the upper 50 cm of an argillic horizon;
b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kanhapludults

3) FCE. -----------Paleudults

4) FCF. -----------Rhodudults

3) FCG. -----------Tropudults

3) FCH. -----------Hapludults

Notes for Udults:

1) In Soil Taxonomy no Oxic subgroups are distinguished in the great groups of Udults, except in Tropudults. However, an Oxic subgroup with an "apparent CEC <16 meq/100 g clay in the major part of the argillic horizon" was proposed by G. D. Smith et al. (Pedology XXV, 1, 1975, pp. 5-23). This proposal would become redundant within the context of the present key because the pedons involved would become Kandiudults.
2) Kandic subgroups are required for Fragiudults and Plinthudults, the definition of which would be based on <16 meq CEC/100 g clay (by NH_4OAc) or <12 meq ECEC/100 g clay at the appropriate depth.
3) No Kandic subgroup will have to be introduced in FCE (Paleudults), FCF (Rhodudults), FCG (Tropudults), and FCH (Hapludults). Only the Tropudults have at present an Orthoxic subgroup, which would be confined to pedons having a CEC (NH_4OAc) between 16 and 24 meq/100 g clay at the appropriate depth.

FD. USTULTS (Soil Taxonomy, p. 369)

1) FDA. -----------Plinthustults

FDB. Other Ustults that meet both of the following requirements:

1. Do not have a lithic, paralithic, or petroferric contact within 1.5 m of the surface and either have a lithoplinthic horizon within 1.5 m of the surface or have a clay distribution such that the percentage clay does not decrease by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface, and
2. Have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:
   a. The weighted average of the upper 50 cm of an argillic horizon;
   b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kandiustults

FDC. Other Ustults that have <16 meq CEC/100 g clay (by NH_4OAc) or have <12 meq ECEC/100 g clay in either or both:

a. The weighted average of the upper 50 cm of an argillic horizon;
b. The weighted average of the upper 50 cm of a finer textured subsurface horizon, and the surface horizon has <40 percent clay.

Kanhaplustults

2) FDD. -----------Paleustults

2) FDE. -----------Rhodustults

2) FDF. -----------Haplustults

Notes for Ustults:

1) A Kandic subgroup is required for Plinthustults, the definition would be based on <24 meq CEC/100 g clay (by NH_4OAc) or <18 meq ECEC/100 g clay at the appropriate depth.
2) No oxic subgroups are at present foreseen in FDD (Paleustults), and FDE (Rhodustults), but an Oxic subgroup is listed under Haplustults, which would be confined to pedons having a CEC (NH_4OAc) between 16 and 24 meq/100 g clay at the appropriate depth.

Circular Letter No. 12, October 1979

A. Introduction

This circular letter is primarily intended to discuss the various comments on and reactions to the two previous letters that I received this year. Some letters and verbal communication dealt specifically with changes desired and/or proposed in the content and wording of the two appendices to circular letter no. 11. Some changes can be easily accommodated; others cannot, at least not without further discussion and consensus. All proposals, however, will have a fair chance for a hearing by means of the present letter.

B. Your comments

The amount of factual data received was rather scanty, but from those submitted it appears that the proposals offered in circular letter no. 11 produce a reasonable classification for most pedons. I have, in the meantime, put a fair amount of time in trying to apply the circular letter no. 11 proposals to well described and analyzed pedons in the literature. Again the results were by and large satisfactory. At the moment I am merely filing these results. But I hope to consolidate them at a later stage as supporting material to our finalized proposals. While in Washington in September I had a long talk with R. Arnold who, as you may know, has taken over from J. Mclelland. One of his suggestions was that we should at least list the subgroups of our Kandi great groups that are required or that we think we will need. This will be the next step in the committee's work, but again I will need your (factual) data.

1. On the FTSH (Finer textured subsurface horizon)

   R. Isbell has some difficulties with defining the "mixing requirements" to a depth of 18 cm. (circular letter no. 11, appendix 1, "depth of clay increase"). In tropical and subtropical areas of Australia pedons with an abrupt textural change at less than 18 cm depth are common, and the importance of even a thin, light textured surface horizon on management, especially for pasture, is considerable.

Isbell writes: "in summary, I would not like to see soils excluded from having a FTSH because they had a thin A1-A2 and an abrupt textural change."

My comments: Most pedons with an abrupt textural change at less than 18 cm depth would still have an FTSH if the upper 18 cm are mixed; however in a few the requirements for the FTSH would no longer be met. To accommodate the Australian (and other?) soils I suggest that the FTSH definition be amended as follows: (circular letter no. 11, appendix 1, last page): "be mixed to a depth of 18 cm for the determination of its clay content. The requirement for mixing is waived if an abrupt textural change occurs at a depth of 5 cm or more, but less than 18 cm." The addition is underlined; the minimum depth of 5 cm + for the abrupt textural change is suggested by Isbell, who also invites your comments on excluding abrupt textural changes from the mixing requirements.

Isbell proposes a further addition to the "depth of clay increase," a paragraph to be inserted at the end of this paragraph (circular letter no. 11 appendix 1), "In other cases the comparison will be made between the top and bottom of 30 cm increments further down the pedon."

R. Arnold suggests that, for the FTSH, the thickness requirements of the argillic horizon are not followed, as was done in circular letter no. 11, appendix 1, p. 127, last paragraph. In the absence of a lithic, paralithic, or petroferric contact the FTSH should be at least 30 cm thick. In the presence of a lithic, paralithic, or petroferric contact immediately below the FTSH this horizon should be at least 15 cm thick.

This would imply that finer textural lamellae or thin layers which do not have clear properties of an argillic horizon would be excluded from the definition of a FTSH.

The possible presence of a lithic, paralithic, or petroferric contact in Kanhaplo taxa has to be incorporated in the definitions of this taxa. With Arnold I also discussed the somewhat controversial wording of the section pertaining to the maximum allowable depth of a diagnostic clay increase (circular letter no. 11, appendix 1, p. 126).

A difficulty is whether we should use the upper or lower boundary of the horizon in which the clay increase occurs (which, by definition, should be less than 30 cm thick). I suggest that the lower boundary of the transition horizon, which corresponds with the upper boundary of the FTSH, be used. This would be analogous to footnote 4 on p. 385 of Soil Taxonomy pertaining to the upper boundary of an argillic horizon, stating that: "If the properties of an argillic horizon are present, but the upper boundary is gradual, use the depth at which the percentage of clay exceeds that of a higher lying horizon by the appropriate amount after fitting to a smooth curve."

If we do this, the paragraph should be reworded as follows:
"By convention, the maximum allowable depth of the upper boundary of a FTSH is made to depend on the clay content and particle size class of the overlying layers or horizons as follows:

1. If the clay content is 20 percent or more, the upper boundary should occur at less than 100 cm from the surface.
2. If the clay content is less than 20 percent, and the particle size class of part or all of the upper 100 cm is finer than sandy or sandy skeletal, the upper boundary should occur at less than 125 cm from the surface.
3. If the particle size class of the upper 100 cm is sandy or sandy skeletal (the texture is sand or loamy sand), the upper boundary should occur between 100 and 200 cm from the surface in the major part of the pedon."

Note that class 3. above is specifically listed to accommodate Grossarenic subgroups.

R. Schargel points out that the "mixing requirement" may change the diagnostic texture, and hence the classification, of soils. His example of a pedon with "kandi" properties:

0-4 cm: 20 percent clay (epipedon)
4-18 cm: 50 percent clay
19-60 cm: 65 percent clay

Mixing to a depth of 18 cm would give an average clay content of 43 percent clay. This would take the pedon out of the Kandi taxa as the key is now worded. My comment: such a pedon would most probably have an abrupt textural change, for which the mixing requirement is waived according to the proposal of R. Isbell.

J. Bennema proposes to join the definition of the rate and the amount of a clay increase as being two aspects of the same thing. He also proposes to simplify the definition of the amount of clay increase (circular letter no. 11, appendix 1, page 127). This amounts to joining the 2. and 3. parts of the definition, stating that the clay increase over a maximum of 30 cm should be 40 percent relative or 16 percent absolute in the case that the horizon overlying the FTSH have >20 percent total clay. This is, I think, acceptable. The present definition tries to follow closely the wording used for an argillic horizon in Soil Taxonomy (p. 27, sub 1), but a simplification is always welcome.

M. Leamy states that he would welcome the addition of a "FTSH" which would have application in N.Z. He also insists that the argillic horizion should have precedence as a diagnostic tool in the classification. This, in my opinion, is right: as it now stands, I see the FTSH mainly as a tool in those cases where the present definition of the argillic horizon, as used in the field, is ambiguous. In this sense I would like to reply to remarks by C. Sys and to the implied comment of H. Eswaran, who insist that "to be or not to be an argillic," the argillic horizon should have clay skins, identifiable in the field, and cutans in these sections in some part of the top 125 cm of the soil surface. There is no doubt in my mind that such a horizon should be an argillic horizon, but it is not necessary that such a horizon is, at the same time, a FTSH, since the latter is not defined on clay skins, but solely on clay increase. Otherwise stated: Argillic horizons may (and often are) at the same time be FTSH, but the "argillic nature" of an FTSH is uncertain as measured against the occurrence of clay skins.

W. Sombroek finds the FTSH useful "in addition to the traditional argillic with clay skins." To him the name is cumbersome and, as possible names, he suggests:

--textural horizon (in analogy to the old B-textural of the INEAC mapping in Zaire),

--lixic horizon, or

--lixo-argillic horizon.

The name of FTSH is indeed cumbersome and we should find and define an alternate. Any further suggestions?

With Sombroek, I believe that quite often the FTSH is a result of the process called "apprauvrisement" in the French literature, i.e. loss of clay from the surface horizon without corresponding accumulation of the illuviated (or broken-down?) clay below. In the new classification system, proposed by P. Segalen et al.*, the name "horizon bulgique" (from the English bulge) is used, and this notion surely is closely related to our proposed FTSH.

2. On the key to great groups (circular letter no. 11, appendix 2)

--The use of "epipedon" in the definition of Kandi- and Kanhaplo taxa is incorrect. This was used in conjunction with the FTSH. (See for instance: HAD, sub B or HCD, sub 2b). I suggest that we replace epipedon in all instances by "the overlying horizons have <40 percent clay."

--Inadvertently, both the terms "lithoplinthic horizon" and "lithoplinthic contact" have been used. The latter is incorrect, so please replace "contact" by "horizon" in the definition of FAD (p. 131-132), FBC (p. 133), FCC (p. 134) and FDB (p. 135). The "lithoplinthic horizon" is used according to the definition of G. Smith (Soil Sc. Soc. Amer. J. 41, 1977, pp. 1212-1214). It is "a horizon of indurated ironstone containing many irregular, tubular channels filled with fine earth that conduct water and permit plant roots to reach underlying horizons." For this reason, the presence of such a horizon is permitted in the deep Kandi taxa. On the other hand the petroferric contact (Soil Taxonomy p. 50) in the definition

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of the Kanhaplo taxa is equated with a lithic or paralithic contact. C. Sys proposes to admit both the lithoplinthic and the petroferric contact in the deep Kandi taxa.

Your comments, please.

--An important point is raised by Sys, as regards the diagnostic CEC (NH_4OAc at pH 7). He prefers to define the Kandi taxa of Ultisols using the 24 meq limit, rather than the 16 meq limit as has been done in the present key (see circular letter no. 11, appendix 2, p. 131 and following). His arguments are based on studies in W. Africa, where many of the Ustults in the savanna region have a CEC/100 g clay in the diagnostic part of the B_t horizon that "straddle" the 16 meq value. Such soils, however, could be classified as Kandi taxa if the 24 meq limit were used. I tend to agree with Sys based on my own data of a similar area. Also, while studying taxa from Puerto Rico (Soil Survey Investigations Report no. 12), it appears that only one of the Ultisols pedons now classified as Oxic (Orthoxic) subgroups has indeed a weighted CEC (NH_4OAc) of the upper 50 cm of the argillic horizon of less than 16 meq. Using the ECEC instead, 7 out of 15 pedons have an ECEC of less than 12 meq/100 g clay, weighed over the upper 50 cm of the B_t horizon. The meaning of this is that, at least for Puerto Rico, the present Oxic and Orthoxic subgroups would be split as regards their classification as "Kandi" taxa. S. Buol's argument that the 16 meq limit would distinguish between kaolinitic and mixed clay mineralogy classes does not hold for the Puerto Rico data. Of the 15 pedons studied, the kaolinitic families have an average NH_4OAc CEC of 19.8 $\pm$ 2.6 meq (ECEC 11.7 $\pm$ 5). The figures for the mixed families are 19.2 meq $\pm$ 4.3 (ECEC 13.7 $\pm$ 3.7) and for the oxidic families 19.5 $\pm$ 0.3 (ECEC 10 $\pm$ 1.8). It appears to me, therefore, that the argument regarding the 16 or 24 meq diagnostic value in Ultisols is still wide open and that further testing is needed to decide one way or the other.

--R. Isbell correctly points out that the definitions of the Kanhaplo taxa (and of the Kandiaqualfs) are incomplete. As already alluded to in circular letter no. 11, appendix 2, page 128, sub (3), Isbell writes:

"both the argillic and the FTSH can be less than 50 cm thick" and this would indeed be the case for pedons, where a lithic, paralithic or petroferric contact occurs in the argillic horizon or the FTSH at a depth of less than 50 cm from the top of such a horizon. The definition of the Kandiaqualfs and of the Kanhaplo taxa therefore have to be changed. Taking the definition of HCE: Kanhaplustalfs (circular letter no. 11, appendix 2, p. 129) as an example, the revision may be as follows:

HCE: Other Ustalfs that have <24 meq/100 g clay (by NH_4OAc) or have <18 meq ECEC/100 g clay in either or both:

a. The weighted average of the major part of an argillic horizon;
b. The weighted average of the major part of a finer textured subsurface horizon, and the overlying horizons have <40 percent clay.

This definition is, admittedly, somewhat vague but would catch all cases in which the argillic horizon or the FTSH would be less than 50 cm thick by virtue of the occurrence of a lithic, paralithic, or petroferric contact or of a coarser textured horizon. It should be pointed out that the minimum permissible depths of the argillic horizon and of the FTSH are included in their definition. The "major part" in the above definition would be at most 70 cm (approximate) in the case of a transition between a Kandi and a Kanhaplo taxon."

3. Other points raised

Some other points were raised in your letters. Some queries I have answered in direct correspondence or discussions. Others are mentioned here, without a specific order.

H. Eswaran is "still not convinced of using a straightforward clay increase to define even the finer textured subsurface horizon," and illustrates this concern with various examples of pedons, c.q. pedons 103 and 104 of Soil Taxonomy (resp. pp. 688 and 689). In my opinion, those two pedons would remain in Oxisols, even if they have a FTSH, because the clay content of the upper 18 cm is over 40 percent.

C. Sys remarks that, with the proposed rules, the classification of (Kandi) soils with less than 40 percent clay in the topsoil is based on fossil clay movement; for soils with more than 40 percent clay we are giving priority to weathering, even if (this) clay increase should be present. He (and others) also points out that the introduction of a FTSH which is not an argillic horizon should be reflected in a definition change of Alfisols and Ultisols. This is true, of course, and it has our attention.

W. Sombroek points out that the use of "kandic" is linguistically not correct: it should be "Kanditic," in analogy with illitic.

S. Buol found that Paleudalfs have been described in Puerto Rico (Fajardo and Rio Arriba series in the 1977 list and the May 5, 1978 amendments). Based on this (and on his own preference?) he proposes to delete item HEG-1, p. 125 in Soil Taxonomy.

R. Schargel raised several points, apart from those already mentioned above:

--Should the presence of a net positive charge (delta pH $\geq$ 0) override the presence of a FTSH, and should such soils become Oxisols, even if there is a considerable clay increase? (comments, please)

--The limits between Kandi taxa and Inceptisols do not give much trouble. In one case an Oxic Dystropept would change to a Kandiudult, but this placement is preferable from a management point of view.

--For the eventual introduction of Kandi subgroups in Tropudults, Hapludults, Paleudults, and others we should test the use of the CEC (NH_4OAc) range between 16 and 24 meq/100 g clay. The Kandi subgroups with a CEC of less than 16 meq/100 g clay could be reserved to those groups which key out before Kandi and Kanhaplo. (This appears to be a very worthwhile proposal meriting further testing)

--The separation between Kandi and Kanhaplo taxa does not appear justified for Venezuela from a management point of view.

--The paper of W. Sombroek on the different argillic horizons is very interesting: much work is required to prove that the combination of criteria will separate the different kinds of endopedons consistently.

R. Isbell, apart from his contributions already discussed, has sent several graphic clay profiles of "oxic" pedons without a distinct argillic horizon. He remarks that the proposed system (introducing the FTSH) is workable but that there will be some splitting of soils that are alike in properties other than clay increase. He also writes: "as you can guess, I would prefer the FTSH not to be restricted" (to the Kandi and Kanhaplo taxa). In reference to the note in margin 2 c. (circular letter no. 11, appendix 2, p. 130), Ray would like to see soil color brought in at the subgroup level in view of important drainage differences between yellow and/or mottled soils compared to red.

Circular Letter No. 13, May 1980

A. Third International Soil Classification Workshop

For this Workshop, held in Syria and Lebanon from 14-23 April, 1980 your chairman prepared a "state of the art" paper on the activities of ICOMLAC. A summary of this paper was presented in Damascus. Because so few ICOMLAC members were present, and because the proceedings of the workshop will take considerable time to edit, I am adding this paper as addendum (1a and 1b) to this letter.

Part of the discussions generated by circular letter nos. 11 and 12 are incorporated in this paper, but most of the subject matter is a review and a summary of the previous circular letters. Most of the open questions are indicated or at least implied; some have, for brevity's sake, not received attention.

Some changes have been made as compared to the keys of the Kandi great soil groups and to the definition of the FTSH in circular letter no. 11. Proposed correction/changes set forth in circular letter no. 12 were included where appropriate. Changes include:

--The diagnostic CEC (NH_4OAc) or acetate CEC limits are now written as $\leq$24 meq/100 clay for Alfisols and $\leq$16 meq for Ultisols. Corresponding limits for ECEC are $\leq$16 meq and $\leq$12 meq. The "equal to or smaller than" sign corresponds better with the definition of the various oxic subgroups and that of the oxic horizon in Soil Taxonomy.

--The ranking of the great groups has been revised in "HA: Aqualfs" and "FB: Humults" in order to better accommodate the Kandi great groups. These changes are obviously subject to further discussion and agreement. They are proposed so that the Kandi taxa would key out at a comparable place in the various keys. The change of ranking in Humults pertains to Plinthohumults which in the present key (Soil Taxonomy p. 356) key out after the Pale great group. In all other suborders of Ultisols, they key out before the Pale great group.

--The definition of the FTSH (appendix 1b) is revised taking into account previous and current correspondence with several committee members.

B. Current correspondence with members

R. Isbell would not be in favour of C. Sys' proposal in circular letter no. 12 to admit the petroferric contact in the deep Kandi groups. Moreover, he is hesitant to even admit a lithoplinthic contact in these groups because "there will be problems of identification with G. Smith's definition, in that it may be difficult to decide if the channels with fine earth conduct water and permit plant roots to reach underlying horizons." As regards the point raised by R. Schargel in respect to a positive charge to "override" the presence of an FTSH to diagnose an Oxisol (circular letter no. 12, p. 144), Isbell thinks that this point is valid but would like other comments, e.g. of G. Uehara.

The soils with an abrupt textural change at less than 18 cm depth, which were discussed by Isbell (circular letter no. 12, p. 137-138), gave rise to some comments. Some want the waiver, some do not; in the new definition of the FTSH (see appendix 1b) I have added a footnote which I hope will satisfy Isbell, while at the same time not upsetting the opponents of the waiver-clause (S. Buol and J. Bennema).

S. Buol, among various points raised, comments on the question of the diagnostic limit, 16 or 24 meq/100 g clay for Ultisols (circular letter no. 12, p. 142, comment by C. Sys as elaborated by me). He writes: "There is no doubt in my mind that geographical areas are going to be split by either 16 or 24 meq. We can separate by geomorphic surface within a geographic area. I strongly favor looking to possible interpretation limits for criteria rather than geographic bias, which is always limited by our experience." As Buol (and you all) may see, the 16 meq limit was maintained in the present appendix 1a. I do find that the introduction of the 12 meq limit for ECEC as an alternate to the acetate CEC offers a solace "when in doubt." In most Ultisols, where the acetate CEC is between 18 and 24 meq, the ECEC appears to be well below 12 meq. This is true at least in the pedons from my "collection."

J. Bennema raises a number of points which I want to discuss with him personally (after all, we are only 60 km apart) before writing them up. Part of the remarks pertain to the FTSH and, possibly, some may have been taken care of in the new definition (appendix 1b). Bennema points out the difficulties we may expect in interpreting older data (e.g. from Brazil). More specifically, the presence of sand or silt-sized aggregates of the clay may upset the validity of texture data. Moreover, in his opinion, the low bulk density in certain soils high in organic matter may interfere with the interpretation of the textural profile.

C. A name for the FTSH

Some want to retain the acronym FTSH; not one of the terms proposed up to now (bulgic, lixic) is accepted by most. Therefore, herewith a further proposal of two possible terms.

Pelotic: Gr. Pelos = clay, the formative element "pelo" is used in the German class of pelogolen which denotes clay soils. The adjective "pelotic" finds its parallel in the derivation demos-demotic (see Webster's Seventh Collegiate Dictionary, p. 220).

Lutic: L. Lutum = mud or loam. In the present Dutch soil classification, lutum is used to denote the clay fraction (less than 0.002 mm).

Personally I prefer the first of the two terms, for the derivation of which I received assistance from various classics-oriented friends from the universities of Utrecht and Nijmegen. Please let me know your preference.

D. Addendum 2

The information in this addendum was received from S. Holzhey (Fed. Building, U.S. Courthouse, RM 393, Lincoln, NE 68508). I am multiplying the highlights of the progress report, since they are particularly relevant to us. You may want to contact Holzhey for the full text.

E. Testing of our proposals

The SCS feels that the proposals made for the introduction of Kandi taxa of Alfisols and Ultisols are now ready for more extensive testing. This is what R. Arnold told me when he visited the Netherlands just recently. The format of the interim publication to be tested will be determined by SCS but, of course, our committee would have a continuing role in this and in evaluating the results of the testing. I hope to visit SCS late August or early September of this year, and plan to discuss matters with SCS. So if you want some "last minute" alterations to what we now have please let me have them by the middle of August.

Appendix 1a to Circular Letter No. 13
(Contribution of F. R. Moormann)

Purpose, Mandate, And Progress of ICOMLAC

A. Introduction

The International Committee on Classification of (Alfisols and Ultisols with) Low Activity Clay Soils (ICOMLAC) was organized in 1975 by the Soil Conservation Service(SCS), USDA. Membership of the committee now stands at approximately 40, up from the original 20 "founding members," representing experts on the soils of the intertropical zone from 19 different countries. Contact between members is mainly by correspondence with the chairman and by circular letters. The twelve circular letters which have been sent out up to January 1, 1980 reflect the difficulties encountered and the slow but steady progress made in fitting "new" soil taxa into the taxonomic framework of Soil Taxonomy (1975). Much progress was made through the personal contact of committee members on various occasions, in particular during the first and second International Soil Classification Workshops (respectively Brazil 1977 and Malaysia-Thailand 1978). The proceedings of these workshops reflect the enormous amounts of work and know-how provided by the members of ICOMLAC, most of whom were invited to these discussions and field tours.

B. Purpose and Mandate of ICOMLAC

The preface of Soil Taxonomy states: "The classification is not equally developed in all parts. The classification of tropical soils ... needs more testing."

Recent soil surveys and related soil research in the intertropical areas have indeed emphasized the necessity for the introduction of additional soil taxa and for a review of the existing ones, including a further study of the differentiating criteria used for their definition.

In the humid tropics (though not exclusively there) a large proportion of the soils show characteristics related to intensive and prolonged weathering. Generalizing, it can be stated that the high degree of weathering is reflected in the mineralogical composition of the clay fraction in these soils. This fraction is dominated by 1:1 layer lattice silicate clay minerals, in particular kaolinite, and by oxides and hydroxides of iron, with common occurrence of gibbsite. Clays with such a composition have been given the generic name "Low Activity Clays" (LAC), whereby the term: "Low Activity" pertains to the low CEC value at any pH value of the clay fraction in these highly weathered soils. Variable charge properties dominate the clay fraction and permanent charge clay minerals such as smectites are either rare or completely absent. The dominance of low activity clays is used as a diagnostic criteria at several levels in Soil Taxonomy:

--At the order level low CEC is implied in the definition of those Oxisols which have an oxic horizon, since one of the properties of the latter is a CEC by NH_4OAc at pH 7 of 16 meq/100 g clay, or less.

--At the subgroup level those Oxic subgroups with a CEC (NH_4OAc, pH 7) of 24 meq or less/100 g clay, in a specified part of the pedon, reflect the dominance of low activity clays. Oxic subgroups occur mainly in the Ultisol order, but are also defined in Alfisols, Inceptisols, and Mollisols. It should be pointed out that no Oxic subgroups were recognized in the great groups of Hapludults and Paleudults because of the assumption that pedons of these taxa mostly would be dominated by LAC. Introduction of Oxic subgroups in the Paleudults great group was proposed by G. Smith (Pedology, 1975, 25-1, pp. 5-24).

--At the family level the mineralogy class (Soil Taxonomy, pp. 386-387) may be indicative, but the criteria are not specifically geared to recognize and classify pedons dominated by low activity clays. More specifically, for the non-clayey particle size classes, clay mineralogy of the <0.002 mm fraction is not diagnostic for the family.

Essentially, therefore, apart from the Oxisol order, only the subgroup level is at present available for distinguishing and defining taxa in which the dominance of low activity clays is an important and measurable property. For various reasons, non-exhaustively listed below, this categorical level was deemed too low by workers involved with taxonomic classification in the intertropical zone:

--Genetically the LAC property is extremely important because it reflects the "state of weathering" in the solum. This is so even though this soil property may be in part inherited from the parent material.

--Taxonomically it appears that in the present Oxic subgroups, in particular those of Alfisols and Ultisols, many quite divergent pedons are grouped in one taxon, and Soil Taxonomy (1975) does not provide for further differentiation at a level above the family or even above the series. This leads to a confusing impression of the geographical distribution of "Oxic" taxa, indicating a non-existing uniformity of soils in many areas of the tropics. Moreover the number of taxa used to subdivide LAC soils stands in no relation to the possibility of subdivision of better known taxa in e.g. the temperate region of the U.S.

--In terms of management-related properties the LAC soils greatly and fundamentally differ from soils dominated by higher activity clays of the 2:1 layer lattice type. It seems unsatisfactory to leave distinction of these differences to such a low categorical level as the subgroup. The purpose of the work of ICOMLAC, therefore, is to remedy this imbalance of the present version of Soil Taxonomy. The mandate of ICOMLAC is to recommend to the SCS changes in the classification of Alfisols and Ultisols dominated by low activity clays, and to define such LAC taxa, as well as the diagnostic properties required for such definitions. It should be noted that the mandate is limited to the Alfisol and Ultisol orders; it is expected however, that the proposed amendments will be valid for LAC taxa in other orders. Implied in the mandate is that amendments should "retain, as far as practical, the groupings currently used, and define the limits of each class as objectively and precisely as practical." (SCS, 1974, Procedures for Amendments of Soil Taxonomy - Directive, p. 6)

C. Discussion of Progress made

On first sight it seemed relatively simple to achieve the goal outlined in the mandate of ICOMLAC. Indeed, in a number of taxa at the great group level in Alfisols and Ultisols provision was made for "Oxic" (Orthoxic, Ustoxic, etc.) subgroups. Thus, it appeared that all that was needed was the upgrading of these subgroups to higher categories in Soil Taxonomy and the extension of these upgraded Oxic subgroups to other taxa in Alfisols and Ultisols. However, in the course of the work of ICOMLAC it became clear that various problems had to be solved and solutions to be agreed upon pertaining to matters which in Soil Taxonomy were (of necessity) dealt with incompletely.

The main groups of problems around which our study has centered are:

--level of classification of the LAC taxa in Alfisols and Ultisols, including nomenclature of the new taxa,

--diagnostic criteria to be used for delineating the proposed new taxa,

--relation to existing taxa in Soil Taxonomy and place in the keys of the new taxa, and

--subdivision of the new taxa at lower categorical level(s).

Considerable progress has been made in the first three items mentioned, as detailed below. The fourth item is still very much under discussion and no complete proposals could (or can) be made in view of a lack of firm field and analytical data. Hence, only a tentative report can be given on this item.

1. Level of Classification and Nomenclature

Two levels above the subgroup were considered, i.e. order and great group. The diagnostic properties used for the suborder level (mainly soil climatic) clearly do not fit the requirements of ICOMLAC.

The distinction at the order level would either require creation of a new order or the change of the definition of the Oxisol order in such a way that all pedons dominated by low activity clays could be incorporated in this order. Although this solution would seem advantageous from a soil genetic and soil mineralogical point of view (i.e. grouping of all soils with dominance of 1:1 layer lattice clays and/or (hydr)oxides of Fe and Al), it would clearly not fit the requirements of the mandate. Indeed such amendments would require a complete overhaul of important portions of the present Soil Taxonomy and present groupings could not be retained, while the taxonomic advantages of such a placement of LAC pedons can be strongly queried. This severe disadvantage does not present itself if the LAC Alfisols and Ultisols are distinguished at the great group level where from taxonomic-cartographic, soil management, and (to a certain extent) genetic viewpoints the separation would be meaningful. It therefore was decided to use the great group level as the appropriate level to introduce LAC taxa in Alfisols and Ultisols.

The nomenclature proposed for these taxa is based on two formative elements, i.e. Kandi and Kanhaplo. The connotation of these names is the relative importance of 1:1 layer lattice silicate clays, and more specifically of kaolinite in the pedons belonging to these new taxa.

For technical taxonomic reasons, and based on a similar distinction of existing taxa at the great group level, it is recommended to use the formative element "Kandi" for the deeply developed LAC pedons and "Kanhaplo" for the less deep pedons. To a great measure these two kinds of LAC great groups are parallel to the present "Pale" and "Hapl" great groups distinguished in various suborders of Alfisols and Ultisols.

Where the LAC properties have a lesser priority in the naming of great groups, such as is the case for existing "plinth" great groups, Kandic subgroups are to be introduced.

2. Diagnostic Criteria

The argillic horizon

Soil Taxonomy requires Alfisols and Ultisols to have an argillic horizon, as discussed and defined on pp. 19-27. An argillic horizon has to contain illuvial layer lattice clays and must have either a specific clay increase, compared to an eluvial horizon, or clay skins (or oriented clay bridges), or both (p. 27 summary of properties). Problems arise in many pedons of LAC Alfisols and Ultisols where clay skins cannot irrefutably be identified in the field and/or by microscopic study of thin sections. In many cases such supposed argillic horizons have most of the characteristics of an oxic horizon (Soil Taxonomy, pp. 36-41) and such pedons would be classified as Oxisols were it not that a clear, non-sedimentary, increase of clay content is found.

Similar difficulties are met with in the distinction of certain LAC Alfisols and Ultisols from Inceptisols dominated by low activity clays. These cases are, however, much less frequent. While the reasons for this apparent lack of clay skins as a result of illuviation are not altogether clear, it appears that the high biological activity under tropical humid and subhumid conditions may be involved. Destruction of clay skins by termites, for instance, is an established fact.

Also other mechanisms for the loss of clay from the "eluvial horizon" may be operative, such as selective erosion of the clay-sized particles from the surface layer or a complete breakdown of layer lattice clay and leaching of its constituents without corresponding enrichment in the horizons below (appauvrissement and ferrolysis). In all these cases the process of clay loss from a surface horizon that has been, or still is, active results in pedons with a subsurface horizon answering the textural requirements for an argillic horizon but with no or no clear clay skins or clay bridges between sand grains.

In order to facilitate the taxonomic distinction between Oxisols and LAC Inceptisols on the one hand, and LAC Alfisols and Ultisols on the other, a new diagnostic soil characteristic has been proposed. In cases discussed above use can be made of the presence of a "finer textured subsurface horizon" (tentatively the abbreviation FTSH is used) which is defined in appendix 1b. It should be pointed out that the FTSH does not replace the argillic horizon in diagnosing LAC Alfisols and Ultisols. It is only used in such cases where a clear textural horizon differentiation is present without a corresponding observable presence of clay skins or clay bridges between sand grains. Although the definition of the FTSH is given in general terms we cannot go beyond the recommendation that it be used for the pedons and taxa falling under the mandate of ICOMLAC.

<u>Charge properties of LAC--the CEC criterion</u>

The clay fraction of the LAC Alfisols and Ultisols is dominated by 1:1 layer lattice silicate clays (mainly kaolinite) and/or by the (hydr)oxides of Fe (mainly goethite and hematite) with the frequent presence of Al hydroxide (gibbsite). Ideally the LAC property should, therefore, be measured by the quantitative determination of the mineralogy of the clay fraction. In reality reliable routine methodology for such an analysis does not exist; so the mineralogy of the clay fraction at present cannot be more than an accessory property of "low activity." Charge properties of low activity clays are anything but uniform. At most it can be stated that the permanent charge of these clays is low though (as in the case of kaolinite-dominated soils) usually measurable.

Relatively speaking the variable (or pH-dependent) charge is moderate-to-high, especially in cases where the layer lattice silicate clays are scarce. Purposely allophanes and related minerals which have a high negative charge at higher pH values have been excluded from the committee's LAC taxa so that the newly proposed Andisol order (as well as andic subgroups) is excluded from our consideration. Many accessory properties to "low activity" of the clay fraction, as defined here, have been studied or are under study. Some are: plasticity index, swelling potential, anion adsorption and phosphate fixation, aggregate stability, chemical dispersion, ZPC and delta pH, silica-sesquioxide ratio, degree of weathering, and others. While some of these properties show a reasonable degree of covariance with the low permanent charge (and, hence, the low CEC), no firm correlation can be presented. Thus, at best, most of the properties named may provide supporting evidence of low activity without by themselves or even in combination being usable as indisputable diagnostic properties of the LAC taxa. For these reasons ICOMLAC is following the present procedure of Soil Taxonomy for characterizing the charge properties of the clay fraction, notably by determination of the CEC of this fraction (in meq/100 g clay).

Soil Taxonomy uses within the Alfisol and Ultisol orders various methods of analyses for the determination of CEC and its derived values (base saturation):

--CEC by sum of cations (5A3a*),

--CEC by NH_4OAc at pH 7 (5Ala, 5A6a), and

--Cation retention from NH_4Cl.

* Method code refers to Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples, Soil Survey Investigation Report 1, SCS, USDA, 1972.

ICOMLAC proposed to drop the latter and to add:
--ECEC: sum of extractable bases (5B4a) plus 1N KCl extractable Al, at the pH of the soil.

The CEC values are expressed in meq/100 g clay; the base saturation is in percent.

The NH_4OAc CEC is used for the distinction of LAC Alfisols and Ultisols from the other taxa of these orders as follows:

Kandi taxa of Ultisols should have a NH_4OAc CEC of $\leq$16 meq/100 g clay in the upper 50 cm of an argillic horizon or of a FTSH. Kanhaplo taxa of Ultisols should have a NH_4OAc CEC of $\leq$16 meq/100 g clay in the major part of an argillic horizon or of a FTSH.

For the Kandi and Kanhaplo great groups of Alfisols the diagnostic value of the NH_4OAc CEC is 24 meq/100 g clay. The depth requirements mentioned above for Ultisols are the same for Alfisols.

ECEC was introduced as an alternate to NH_4OAc CEC. For Ultisols, the ECEC should be $\leq$12 meq/100 g clay at the diagnostic depth; for Alfisols this value is 16 meq.

ICOMLAC recognized the fact that the CEC criterion is not an ideal one. NH_4OAc CEC analysis is laborious and subject to many sources of error, especially at the low values common for the LAC taxa. The advantage is that it is a common and internationally widely used method and, furthermore, that the pH dependency of the data for CEC is eliminated by introducing one reference pH (i.e. pH 7). This immediately indicates the disadvantage of ECEC, which indeed changes where soil management changes the pH of the diagnostic horizons (e.g. by deep liming). Thus a soil which is classified as a (marginal) LAC taxon may "lose" its LAC property by soil management when the ECEC is used as the exclusive diagnostic value. Clearly more research has to be done on current and alternative CEC (and AEC) determinations and on accessory properties to fit the requirements for a reliable diagnosis of LAC taxa.

Soil temperature as a diagnostic criterion

In the course of ICOMLAC's discussions it was decided to recommend that the criteria used for distinguishing the present "Tropo" great groups of Alfisols and Ultisols should not be used in the classification of LAC taxa at the great group or subgroup level. While most LAC pedons have a warm iso-soil temperature regime, some have a non-iso regime. This distinction, important for management, will be made at the family level.

Fe and Al in the fine earth and clay fractions

Dominance of Fe (hydr)oxides or Al hydroxides (gibbsite) in the fine earth and in the clay fraction has important soil genetic and morphological implications and is also important from a soil management point of view. Soils high in such compounds have, among other characteristics, a more stable structure, a greater microporosity, and a soft or friable consistence irrespective of moisture content. Due to the dominance of compounds with a relatively high ZPC over layer lattice silicate clays such soils have often a relatively high anion "fixing" capacity (e.g. of phosphorus). Other properties, as for instance the high specific surface of clay-sized "active" Fe (hydr)oxides, are now being studied.

Under discussion in the framework of ICOMLAC is the desirability to distinguish the LAC pedons with the above-mentioned properties at the great group level. A good portion of pedons classified under the present "Rhod" great groups and Rhodic subgroups have these properties, but the criteria used for the "Rhod" concept are fundamentally different and not all pedons belonging to "Rhod" taxa have the above properties.

No definite recommendations on this subject can be made at the present time.

3. Relations to Existing Taxa--Great Group Keys

Two sets of relationships of LAC taxa with other taxa of Soil Taxonomy had to be established. First a boundary had to be defined between LAC taxa of Alfisols and Ultisols with Oxisols and (LAC) Inceptisols. Second the place of the LAC taxa in the existing great soil group keys of Alfisols and Ultisols was to be established.

Following is a summary of the proposals for which agreement was reached in ICOMLAC.

Limits between LAC Alfisols and Ultisols and soils of other orders

To distinguish LAC Alfisols and Ultisols from Oxisols the LAC Alfisols and Ultisols must have one or both of the following:
--an argillic horizon with clay skins discernable both in the field and in the thin sections, and/or
--a FTSH and the overlying horizons have <40 percent clay.

To distinguish LAC Alfisols and Ultisols from LAC Inceptisols the LAC Alfisols and Ultisols must have one or both of the following:
--an argillic horizon, and/or
--a FTSH.

To distinguish LAC Alfisols from LAC Mollisols the LAC Alfisols must not have a mollic epipedon and an oxic horizon. (The latter limit definition is tentative.)

Placing LAC Alfisols and Ultisols in the great soil group keys

Ranking of the LAC great groups varies with suborder but in principle they should have a higher ranking than the existing "Trop," "Pale," "Rhod," "Hapl(o)," "Ochr," and "Umbr" great groups. They should have a lower ranking than the existing "Plinth(o)," "Natr," "Dur," "Fragi," "Fragloss," "Gloss," "Alb," "Sombri," "Agr," and "Ferr" great groups. Where LAC pedons occur in the latter great groups they will be distinguished at the subgroup level. This will commonly be the case for the "Plinth(o)" great groups but rarely or not ever for most of the others.

The present great soil group keys of Alfisols and Ultisols would be modified as follows:

HA. AQUALFS (Soil Taxonomy, p. 109)
HAA. .... Plinthaqualfs
HAB. .... Natraqualfs
HAC. .... Duraqualfs
HAD. .... Fragiaqualfs (*)
HAE. .... Glossaqualfs (*)
HAF. .... Albaqualfs (*)
HAG. .... Kandiaqualfs (at present no Kanhaplaqualfs are proposed)
HAH. .... Tropaqualfs
HAI. .... Umbraqualfs
HAJ. .... Ochraqualfs

HC. USTALFS (Soil Taxonomy, p. 138)
HCA. .... Durustalfs
HCB. .... Plinthustalfs
HCC. .... Natrustalfs
HCD. .... Kandiustalfs
HCE. .... Kanhaplustalfs
HCF. .... Paleustalfs
HCG. .... Rhodustalfs
HCH. .... Haplustalfs

HE. UDALFS (Soil Taxonomy, p. 125)
HEA. .... Agrudalfs
HEB. .... Natrudalfs
HEC. .... Ferrudalfs
HEE. .... Fraglossudalfs
HEF. .... Fragiudalfs
HEG. .... Kandiudalfs
HEH. .... Kanhapludalfs
HEI. .... Paleudalfs

* placement different from a previous proposal.

HEJ. .... Rhodudalfs

HEK. .... Tropudalfs

HEL. .... Hapludalfs

(A great group of Plinthudalfs is probably required).

FA. AQUULTS (Soil Taxonomy, p. 351)

FAA. .... Plinthaquults

FAB. .... Fragiaquults

FAC. .... Albaquults

FAD. .... Kandiaquults

FAE. .... Kanhaplaquults

FAF. .... Paleaquults

FAG. .... Tropaquults

FAH. .... Ochraquults

FAI. .... Umbraquults

FB. HUMULTS* (Soil Taxonomy, p. 355)

FBA. .... Sombrihumults

FBB. .... Plinthohumults

FBC. .... Kandihumults

FBD. .... Kanhaplohumults

FBE. .... Palehumults

FBF. .... Tropohumults

FBG. .... Haplohumults

FC. UDULTS (Soil Taxonomy, p. 360)

FCA. .... Fragiudults

FCB. .... Plinthudults

FCC. .... Kandiudults

FCD. .... Kanhapludults

FCE. .... Paleudults

FCF. .... Rhodudults

FCG. .... Tropudults

FCH. .... Hapludults

* Some changes are proposed in the present Soil Taxonomy to establish a better agreement with the ranking in other suborders.

FD. USTULTS (Soil Taxonomy, p. 369)

FDA. .... Plinthustults

FDB. .... Kandiustults

FDC. .... Kanhaplustults

FCD. .... Paleustults

FCE. .... Rhodustults

FCF. .... Haplustults

4. Subgroups of LAC Taxa of Alfisols and Ultisols

Many of the subgroups defined in Soil Taxonomy for the existing great groups of Alfisols and Ultisols will also occur in the newly proposed LAC great groups. Descriptions of the Typic subgroups must be made based on our factual knowledge of subgroups recognized and described and of subgroups of which the existence can be predicted with a great degree of probability.

An incomplete listing of common subgroups, besides the Typic, would include: Aeric (for LAC Aqualfs and Aquults), Aquic (for other LAC Alfisols and Ultisols), Arenic, Grossarenic, Plinthic, and Psammentic. For part of the LAC great groups subgroups currently identified or to be expected would include: Epiaquic, Abrubtic, Lithic, Paralithic, Fragic, Petroferric, Rhodic, Udic, Ustic, Ultic, Xeric, and composites of those subgroups (multiple subgroups).

The necessity of some, but by no means all, new subgroups specifically required for LAC taxa were discussed.

"Acric" subgroups would be required in LAC taxa of Ultisols for intergrades towards Acrohumox, Acrorthox, and Acrustox. The diagnostic property of such subgroups to be tested is that pedons should have an ECEC of less than 2.5 meq/100 g clay in some subhorizon of the argillic horizon and/or the FTSH.

"Vadic" subgroups were proposed for such pedons which are not hydromorphic enough to be considered as an aquic subgroup but which show moderate to strong iron segregation frequently due to seasonal interflow-water saturation. Subgroups would be required to differentiate soils belonging to the same great groups but which are respectively poor or relatively rich in weatherable minerals. Pedons with more than 10 percent weatherable minerals might go with a "caric" subgroup.

D. Concluding remarks

The foregoing chapter is a review of the progress made by ICOMLAC towards fulfilling the task spelled out in its mandate. A consensus has been reached on major points and the draft proposals are, by and large, ready for field testing. This is a necessary task which largely remains to be done and requires cooperation with soil scientists from the lower latitudes. Another task which has been started but not completed is implied in the aforementioned "Proceedings for Amendments." This is that the impact of each and all proposed changes on the definition of all taxa that will be affected must be described. Because the modifications that ICOMLAC wishes to propose are major ones this is still a considerable task.

Appendix 1b to Circular Letter No. 13

Finer Textured Subsurface Horizon (FTSH)

Many soils have subsoil clay contents greater than in their surface horizons. Many such soils are recognized as having argillic or natric diagnostic horizons. However, there are many soils where the genetic processes for forming a higher clay content in the subsoil cannot be agreed upon by pedologists. Clay skins are not readily evident to indicate formation by the lessivage process. Several alternative processes may create this morphological feature. It is possible that clay in the surface horizon may have been removed from the soil by erosion. Certainly much of the clay in the subsoil has been formed in situ from weathering by larger sized primary minerals. Also it is possible that in many soils, especially those formed in transported materials, textural lithologic discontinuities may be present between the topsoil and the subsoil but evidence for such discontinuities is extremely difficult to establish because of extensive weathering and other pedogenic processes. While it is not desirable to include in this definition finer subsoil textures that are clearly the result of fluvial activity, as evidenced by geogenetic fine layering or by irregular organic matter contents with depth, it may include subsurface horizons where a fluvial origin is expected providing the horizon has granular, single grain, or blocky structure or is massive or structureless. While these features can be determined from the examination of an individual pedon, it is often prudent to examine several pedons in similar geomorphic settings to determine the lateral continuity of finer textured subsoil horizons. Specific diagnostic limits of a finer texture subsurface horizon should include:
--thickness of the FTSH,
--rate of clay increase with depth,
--amount of clay increase, and
--depth of the FTSH.

1. Thickness

An FTSH should be at least 30 cm thick in the absence of a lithic, paralithic, or petroferric contact, or should be at least 15 cm thick immediately above such a contact.

2. Rate of Clay Increase

The diagnostic increase in clay from an overlying horizon to the FTSH is reached within a vertical distance of 30 cm or less.

3. Amount of Clay Increase

The FTSH contains more total clay than the overlying horizon as follows: (1) if any part of the overlying horizon(s) has less than 20 percent total clay in the fine earth fraction the FTSH must contain at least 7 percent more clay; or (2) if the overlying horizon(s) has more than 20 percent total clay in the fine earth fraction the ratio of clay in the FTSH to that in the overlying horizon(s) must be 1.4 or more or the FTSH must contain at least 16 percent more clay.

4. Depth of the FTSH

By convention a minimum and a maximum allowable depth is set between which the upper boundary of an FTSH should fall in order that the horizon is diagnostic. To exclude the very thin coarser textured surface horizons, easily destroyed by cultivation practices such as plowing, the upper part of the pedon should be mixed to a depth of 18 cm for the determination of its clay content.* This sets the minimum depth of the upper boundary of an FTSH at 18 cm.

In practice comparisons are usually of the mixed sample of the upper 18 cm and the sample at a depth from the surface of 43-48 cm, or between the top and bottom of a 30 cm increment further down the pedon.

By convention the maximum allowable depth of the upper boundary of an FTSH is made to depend on the clay content and particle size class of the overlying layers or horizons as follows:

* For some undisturbed pedons under continuous pasture or natural vegetation, the requirement for mixing the upper 18 cm is waived if an abrupt textural change occurs between 5 and 18 cm depth.

a. if the clay content is 20 percent or more, the upper boundary should occur at less than 100 cm from the surface,

b. if the clay content is less than 20 percent, and the particle size class of part or all of the upper 100 cm is finer than sandy or sandy skeletal, the upper boundary should occur at less than 125 cm from the surface, or

c. if the particle size class of the upper 100 cm is sandy or sandy skeletal (the texture is sand or loamy sand) the upper boundary should occur between 100 and 200 cm from the surface in the major part of the pedon.

Circular Letter No. 14, February 1981

A. Nomenclature of the FTSH

My proposal to call the FTSH a pelotic horizon appears not appropriate. H. Eswaran now proposes to use the term "kandic horizon." The implication is that the FTSH, so named, should have the kandic properties of a dominance of low activity clays. And, to my way of thinking, this is just what we are after. So until further notice the term "Kandic horizon" is used for the finer textured subsurface horizon, the concept of which was developed in previous circular letters.

B. Letters received and subjects discussed

Most letters received after circular letter no. 13 are discussed here:

1. J. D. Nichols, who with his group has done considerable work on applying the ideas developed in circular letter nos. 11 and 12, addresses the problem of the control section for the kandi and kandic properties which, as you know, has up to now been determined as being the "upper 50 cm of an argillic or a kandic horizon." Data from the U.S. and from Kenya indicate that frequently the CEC/100 g clay decreases with depth. Often values in the upper part of the present control section are above the critical values for kandi while the real low CEC values are found between 100 and 200 cm. Nichols indicates that this trend was not found in the pedons studied in Brazil (Proceedings of the 1st workshop). In my own collection of pedons from Nigeria I found this decrease in 16 out of 23 relevant pedons.

   Indications are, therefore, that we should change the CEC control section for Kandi-taxa. In Nichols' letter no definite proposal is given for new limits of the control section, but it is pointed out that oxic horizons are definitive if within the upper 200 cm and below 15 cm depth, while Oxic subgroups are based on failing the requirement for Typic as regards CEC in the major part of the argillic horizon. If we would follow the latter, we would have to include with Kandic those pedons which have a low CEC in the major part of the argillic or the kandic horizon.

The use of a control section at a greater depth would have a further advantage for the Kandi-taxa of Humults because the effect on CEC of the organic matter in the upper part of the profiles would be largely cancelled.

Based on Nichols' and my own data I would therefore propose a change in the definitions of the Kandi and Kanhaplo taxa from those given in appendix 2 of circular letter no. 11. In the various definitions one should read now:

"have x meq CEC/100 g clay (by NH_4OAc) or
have y meq ECEC/100 g clay in either or both:
a. the major part of an argillic horizon
b. the major part of a kandic horizon and ..."

This alternative definition has the advantage of removing the ambiguity in the present definition of Kanhaplo taxa (see note no. 3 in margin, p. 130, appendix 2, circular letter no. 11).

Further points discussed in Nichols' letter include:

--Kandi taxa will be needed for Inceptisols with a low CEC but that do not meet the requirements for an Oxisol, e.g., because of having too high a content of weatherable minerals. Kandi taxa may also be needed for Mollisols. I agree with Nichols but suggest we tackle this problem after the present exercise is brought to a good end.

--The FTSH (Kandic horizon) concept will cause the placement of some soils that lack the 1.4 ratio clay increase, yet do not quite make Oxisols because of chemistry or weatherable minerals, into Inceptisols. The result will be a lowering of the number of Alfisols and Ultisols and an increase in Inceptisols.

Again, I have to agree with Nichols that this is what will happen unless such pedons show clear signs of clay translocation in the form of clay skins. For the problem of the ratio-increase required for the kandic horizon see below where I present S. Buol's letter.

2. A. Herbillon's letter is chronologically the next one. In his laboratory, a study was made on HAC and LAC soils on materials from basic rocks, all belonging to very fine clayey families.

a. The following measurements were made:

(1) CEC by NH_4OAc at pH 7: here indicated as NH_4OAc CEC.
(2) ECEC.
(3) CEC acc. to Gillman and Bakker (Proc. 2nd Int. Soil Class. Workshop II, 1979, pp. 77-90): here indicated as ceCEC. The "ce" stands for "compulsive exchange."
(4) AEC acc. to Gillman and Bakker.
(5) ISR_1 (Gallez et al. 1977, see also Proc. 1st Int. Soil Class. Workshop 1978).
(6) ISR_2: a modified determination of the Index of Silica Reactivity.
(7) IPR: Index of Phosphorus reactivity (Juo and Fox 1977).

b. A summary of results:

(1) Following functions give the relations between the various CEC values for the samples studied:

NH_4OAc CEC = 6 + 1.28 ceCEC (r = 0.985)

ECEC = 1.7 + 0.8 ceCEC (r = 0.99)

(2) The relations between mineralogical composition of the soils and the surface charge properties are given in Table 1. To simplify, I have used the numbers 1-7 (see 2.a. above) for the ratios and values tabulated.

Table 1.

Family	(1-5)/1	4	3-4	5	6	7
montmorillonitic	0.26	0	+ 50.9	25	63	23
mixed	0.39	0.12	+ 18.5	48	68	42
kaolinitic (1)	0.61	0.24	+ 2.6	41	53	45
(2)	0.59	0.45	+ 2.2	37	46	36
(3)	0.66	1.31	+ 4.0	53	101	86
oxidic	0.90	2.98	- 2.2	54	90	69
gibbsitic	0.86	1.29	- 0.5	60	123	34
	1.00	3.69	- 3.7	71	180	75

(3) The ratio (1-5)/1 is a good approximation of the theoretical ratio: variable (pH dependent) charge/total charge of pH 7 with NH_4OAc. This ratio may be used to distinguish between HAC and LAC materials (when in doubt) and between mineralogy families.

(4) The difference (3-4) may well be of interest for recognizing acric soil materials (negative values) and for the definition of clay mineralogy classes.

(5) The reactivity of oxide surfaces, as expressed by ISR_1 (5), ISR_2 (6), and IPR (7) are not very well related to the difference (3-4). Indeed, 5, 6, and 7 do not measure an electric charge but rather the affinity for specific anions.

(6) Note the high values for ISR_2 (6) for gibbsitic families: this parameter seems strongly related to the presence of active gibbsite surfaces.

In his letter, A. Herbillion relates the above observations to the two groups that T. Juo distinguished in circular letter no. 8, appendix 4, where the variable (pH dependant) charge is higher for the group B, the oxidic soils, than for the group A, kaolinitic soils.

3. A. Van Wambeke offered a number of comments, most of which were dealt with in direct correspondence. Others are briefly mentioned here.

--Van Wambeke asks if SCS could circulate a list of reference profiles which can easily be found in publications and offer sufficient data to test the new criteria. This certainly seems an excellent idea, which I pass herewith to the SMSS (Soil Management Support Service) of the SCS.

--It is pointed out that we still have no decision whether or not a correction should be made for organic carbon when calculating the CEC/100 g clay. I touch upon this subject later in this circular letter, but a formal recommendation may have to wait the coming International Soil Classification Workshop in Rwanda.

--A further comment on the FTSH or kandic horizon is discussed below.

C. Again the FTSH or Kandic Horizon

Considerable brainwork has been going on as regards this horizon and its definition; in the case of J. Bennema and myself even with the help of a modest computer program. Points of discussion pertain mainly to the latest version of the definition of the kandic horizon as it was written in circular letter no. 13, appendix 1b.

In the following I therefore refer to that specific definition:

1. Amount of clay increase

S. Buol in his letter refers again to the amount of clay increase, i.e., the 7 percent and the 1.4 ratio as defined. Buol correctly remarks that "if the argillic and FTSH (kandic) are not the same then you have to debate clay skins in those between (ratios) 1.2x and 1.4x clay and we have not eliminated the clay skin problems." A. Van Wambeke too states that the present definitions "seems to be quite demanding in terms of clay increase." He adds, however, that he thinks the vertical distance to achieve the required increase (i.e. 30 cm) appears too generous. This added phrase offers a solution as regards the controversy "amount of clay increase," which I will present below.

Let me state, however, my own opinion, which is confirmed by J. Bennema, and which is based on going through a great many data of Oxisols, Ultisols, and Alfisols, so named from various publications at hand. From these data it appears that equalizing the clay increase requirements of the argillic horizon and the kandic horizon would not be a good idea. Even in profiles on isotropic materials some texture differentiation occurs in most soils which, otherwise, have all the characteristics of Oxisols. Thus, this proposal to equalize would strongly diminish the (already somewhat rare) Oxisols. However there seems to be a way out using the second part of the statement of Armand Van Wambeke as the pertinent point. If, indeed, we can decide that the vertical distance to achieve the required increase should be 12 cm or less (instead of 30 cm or less) we can drop the higher ratios.

(Note: This decision was made in the Rwanda Workshop, where the definition of the kandic horizon was finalized.)

In circular letter no. 13, appendix 1b, this proposal would require following changes of diagnostic limits:

2. Rate of clay increase

The diagnostic increase in clay from an overlying horizon to the kandic horizon is reached within a vertical distance of 12 cm or less. (The transition is abrupt, clear, or gradual, but not diffuse.)

3. Amount of clay increase

The kandic horizon contains more total clay than the overlying horizon as follows: (1) if any part of the overlying horizon(s) has less than 20 percent total clay, the kandic horizon must contain at least 4 percent more clay; (2) if the overlying horizon(s) has more than 20 percent total clay in the fine earth fraction, the ratio of clay in the kandic horizon to that in the overlying horizon(s) must be 1.2 or more, or the kandic horizon must contain at least 8 percent more clay.

4. Depth of clay increase

In this paragraph in circular letter no. 13, appendix 1b, replace "... and bottom of 30 cm increments ..." by "... and bottom of 12 cm increments ..." etc.

Changing the definitions in this way, I think, has two advantages. First we may avoid the necessity for another group in Oxisols (Kurorthox) to cater for the cases where the increases follows the 1.2 ratio rule but not the 1.4 ratio rule. Second, the faster increase now required is advantageous from a field-morphology point of view. Such an increase which, by definition, must take place within 12 cm is undoubtedly more conspicuous and easier to recognize in the field.

At this point I should bring in the appendix, entitled "Comparison of clay increase with log (depth + 1) for Brazilian Latosols (Oxisols) and Red-Yellow Podzolic soils (Ultisols and Alfisols)," with its follow-up "Soils with an FTSH and an upper layer with less than 40 percent clay, are they never Oxisols?" J. Bennema sent the first of these two documents to the members and correspondents of ICOMOX, many of whom also belong to ICOMLAC. I am sending copies of this first appendix to ICOMLAC members who did not receive it and I include the follow-up as an appendix to this letter. The main points made in these documents are of importance in our deliberations. As I can see it, Bennema points out that there are pedons on old to very old surfaces developed on isotropic parent materials which show a clay increase as required for a kandic horizon and yet these pedons should be classified as Oxisols. Bennema indicates several processes by which these old soils can lose clay from the surface layers and by which a specific clay-distribution can be reached. If we perform a linear regression between the clay content in percentages and the logarithm of the depth; (i.e., log (depth + 1)), these "Oxisols with a kandic horizon" will give a virtually straight line. In the regression the index of determination r^2, will be close to 1, i.e., 0.92 or more for Brazilian Oxisols with a clay increase, while the standard error of estimate of Y on X, Sy.x, will be low, i.e. less than 2.75 for the same profiles. Carrying out the--what I will call the "Bennema"--regression manually may be time consuming and tedious, however, a programmable calculator greatly reduces the computation time.

I have tried out the Bennema regression on quite a few profiles in the range of Ultisols-with-oxic characteristics and of (so named) Oxisols which may have a kandic horizon. It is too early to decide whether or not the Bennema regression can be used as a diagnostic tool. It is, however, certainly useful to pick out those profiles on isotropic materials which have a clear argillic or kandic horizon. For most such profiles, I find, indeed, values for r^2 and/or Sy.x which are clearly out of Bennema's range for Oxisols. Possibly the safest statement to be made at present is that "some pedons which have a kandic horizon as defined now may have to be classified as Oxisols if the values for r^2 and Sy.x in the Bennema regression indicate a linear increase of clay content with the logarithm of depth, and if otherwise they meet the Oxisol requirements." This is quite a mouthful, but the whole story is very interesting and should be studied further by both ICOMLAC and ICOMOX members.

Yet another very pertinent observation on the kandic horizon was made by S. Buol. His remark pertains to the section: "Amount of clay increase," circular letter no. 13, appendix 1b. He writes: "I think it would be simpler to consider the FTSH (kandic horizon) only after mixing the surface 18 cm and comparing the clay content of the mixture to the minimum clay content that is present within the depth specified."

Applying this proposal indeed simplifies matters, but there are some pitfalls. Thus the weighted average clay content of the upper 18 cm may be (just) below 20, in which case the clay increase should be at least 7 percent (or 4 percent if we follow the earlier mentioned proposal). But the "critical increase" may come deeper in the profile or, otherwise said, the kandic horizon may be situated deeper and at that depth we may have to use the 1.4 rates (or 1.2 if we follow the earlier mentioned proposal) as in the theoretical example I give herewith (7 percent and 1.4 ratio rule):

Horizon no.	Depth (cm)	Clay percentage
1	0 - 18	18
2	18 - 30	22
3	30 - 40	22
4	40 - 50	22
5	50 - 60	30
6	60 - 70	30

If we set the top of the kandic horizon at approximately 50 cm depth there is an increase from horizon 1 to horizon 5 of 12 percent, certainly enough to recognize a kandic horizon. But if we consider a 30 cm portion above the assumed top of the kandic horizon the situation is different. In this portion, say between 25 and 55 cm, the ratio of the clay contents at those depths is 1.36, hence not enough to make a kandic horizon. Inter alia: if you draw the graph of this profile you may see that this profile would clearly have a kandic horizon if we diminish the vertical distance of the diagnostic clay increase to 12 cm (instead of 30) and if we require only a 1.2 ratio of increase. This seems an advantage.

I have gone through a good many "true life" profiles and the situation sketched in the theoretical example does rarely arise. Hence, in practice, we may be all right to follow Buol's suggestion; but we should be aware of the cases where the diagnostic increase occurs lower in the profile.

As to the definition of the kandic horizon or FTST as it now stands, I agree that it is cumbersome and that it is incomplete if compared to the write-up of the argillic or spodic horizon. I am working on completion of the write-up of the kandic horizon and I can assure you that it is intricate. So your help in polishing up the "kandic horizon story" will be appreciated.

D. Correction for Organic C

Going through various letters and notes of discussions I must conclude that we have not yet developed a consensus as to whether or not we should correct the CEC for humus when calculating the "CEC in meq/100 g clay." As it now stands and also as the expression "CEC in meq/100 g clay" is presently used in Soil Taxonomy we determine the CEC for the whole soil and then divide by the clay content. This was already pointed out by S. Buol. This means that no correction is made for organic C.

The most important group making the CEC correction for organic C when calculating the clay-CEC are the Brazilians. They follow the system developed by Bennema (1966) for Oxisols (see also Proceedings of the Brazil workshop). Against making the correction for organic C are several of our U.S. colleagues on these various grounds:

--from a soil management point of view the exchange capacity of the organic C is real, and in management practice it does not really matter very much if part of the exchange properties are determined by organic "colloids" rather than by clay "colloids";

--the introduction of the organic C correction would have significant repercussions in many parts of Soil Taxonomy, and would therefore require a major revision;

--the determination of the portions of the CEC due to organic "colloids" is difficult and, in many cases, not reproducible; e.g., because of the variable nature of the organic compounds in different soils of various parts in the world.

As regards the latter, there are, of course, apart from the Brazil-Bennema method, several alternatives. I will mention a few without intending to be at all complete. A chemical method which I remember from my early days as a soil scientist is the method of destroying organic matter (e.g., by H_2O_2) and then determining the CEC of the mineral residue. The CEC of the organic portion would then be the difference between total CEC and "mineral" CEC of the sample. I understand, however, that values so obtained are at best very approximate, among other reasons because the treatment will strongly influence the surface chemistry of the mineral fraction.

Another "field approach" is used by W. J. Veldkamp of our committee. Veldkamp assumes a constant CEC of the clay fraction throughout the profile which he estimates by using the CEC/100 g clay of the subsoil at about one meter depth (where the organic C content is usually so low as to hardly influence the value for CEC or ECEC). Matching this value with the CEC or ECEC/100 g clay in the horizons high in organic C will give a reasonable estimate of the CEC of organic C. I should point out that this approach has affinities to the approach of J. Nichols dealt with in section B.1 of this letter. As I indicated there, by lowering the CEC control section we would at least get rid of part of the effect of organic C on CEC.

Another method, complete with a computer program for a Hewlett-Packard 25, is given by P. Buurman on p. 125 of the publication "Red Soils in Indonesia" (Agr. Research Report 889, PUDOC Wageningen or Bull. No. 5, Soil Research Institute, Bogor). Essentially--says Buurmann--the CEC of a soil is derived from two compounds, i.e., the organic matter and the clay, assuming that the silt fraction plays a minor role, as in most tropical soils. Hence,

$$CEC_{soil} = n \times C + m \times Clay. \qquad (1)$$

in which n is the CEC of the organic fraction expressed as C, and m is the CEC of the clay fraction. Assuming that n is constant throughout the profile and that m is at least constant in the upper two horizons we can, for these two horizons, write:

$$CEC_1 = n \times C_1 + m \times Clay_1,$$

and

$$CEC_2 = n \times C_2 + m \times Clay_2 \qquad (2)$$

in which the subscripts 1 and 2 stand for the first and second horizon. Hence n can be calculated from

$$n = CEC_1 \times Clay_2 - CEC_2 \times Clay_1)/(C_1 \times Clay_2 - C_2 \times Clay_1) \qquad (3)$$

For the pedons from Brazil (see Proceedings 1st International Soil Classification Workshop) I did some comparisons between the Brazil-Bennema figures and the Buurman data, both in meq/1 g org. C. These are reproduced in the following table:

Profile Nr.	Br-Ben.	Buurman	Profile Nr.	Br-Ben	Buurman
Br1	4	4.5	Br2	7	6.7
Br4	4.4	4.2	Br4	4.4	4.2
Br6	4.8	3.4	Br7	5	2.5
Br8	3.7	4.2	Br9	3.4	.27 (Sic)
Br10	4	3.2	Br11	3.5	3
Br12	4	2.4	Br13	5.5	6.5
Br14	4	2.5	Br16	4.6	3.6
Br21	4.7	4.4	Br23	3.8	5.1
Br24	5.2	4.8	Br25	4	16 (Sic)
Br28	4.4	4.2	Br31	4.8	4.4

A few remarks about these data:

--In Br7 the CEC org. C is 5.3 when we compare horizon 2 and horizon 3 by the Buurman method. Why?

--In Br8 there is a slight mistake in the graph as printed in the proceedings. After correcting this mistake the Br-Ben. values is probably closer to 5.

--The strongly aberrant Buurman-values of Br9 and Br25 are respectively for profiles with a low and a high clay content in the first two horizons. Is there a relation?

Both methods are approximations (at best) for the values of the organic C-CEC. The determining values themselves are approximations: we all know that foolproof analytical determinations really do not exist (as yet). I would therefore think that both methods can be used to get a reasonable idea of the part of the CEC determined by organic matter. In effect, the Veldkamp way, used in Liberia, also gives fairly similar results. And, when in doubt, I would agree with P. Buurman when he writes: "In practice, if calculated values are smaller than 1 or higher than 6, an assumed value of 4 gives good results."

In conclusion of this paragraph let me reiterate the questions that face us, which are:

--should ICOMLAC (and, by implication, ICOMOX) recommend the introduction of a correction for organic C when using the CEC/100 g clay as a diagnostic characteristic?

--if the answer is affirmative should such a correction be proposed for general incorporation in Soil Taxonomy, i.e. in the definition of diagnostic properties of taxa other than the Kandi-taxa?

--by which method or methods should the correction be made.

I. Brazil Workshop

Report on the Brazil Meeting of the Committee on the Classification of Alfisols and Ultisols with Low Activity Clays

F. R. Moormann

A. Introduction

In the preface of Soil Taxonomy it is emphasized that the classification presented, although in principle a universal system, is far from complete and not equally well developed in all parts. The classification of soils of the tropics is mainly based on studies in restricted areas, especially in the State of Hawaii, Puerto Rico, and the U.S. Virgin Islands. Soil taxa definitions for the tropical region at large are hence in a lesser state of perfection and require further attention.

In 1975, the Deputy Administrator for Soil Survey, SCS-USDA, established an international committee with members from many countries to test the established differentiae and classes of tropical soils against the existing knowledge of these soils, their behavior and the relevancy of the classification with respect to geographic distribution and broad management properties of the existing taxa. After an initial review of the numerous aspects of revision of Soil Taxonomy for tropical regions, the committee opted for a specific mandate, i.e., the review of those Alfisols and Ultisols in which the diagnostic argillic horizon is dominated by "low activity clays," mainly 1:1 latice kandites and/or hydrous oxides of iron (and aluminum). In the present classification of the two

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orders, soils with low activity clays are mainly recognized as Oxic (plus Ustoxic and Orthoxic) subgroups. However, for instance in the case of Hapludults and Paleudults, the only possible, albeit incomplete, recognition is at the family level.

The three main arguments for upgrading the low activity clay property of these soils are:

--<u>geographic</u>: the extent of the low activity clay taxa in the intertropical zone is considerable; they are dominant among the Alfisols and Ultisols in this region.

--<u>taxonomic</u>: the distinction of these taxa at a low categorical level leaves little or no freedom to make meaningful further subdivisions. Thus, in the dry forest and savannah zone of W. Africa, a considerable portion of the well drained upland soils should, at present, be classified as Oxic Paleustalfs and, to a lesser extent, as Oxic Haplustalfs, limiting such a wide range of soils to two subgroups. This is clearly not in balance with the subdivision of most taxa in the better known temperate zone of, e.g., the continental U.S. Moreover, in several international systems, such as the CPCS (French) system, and national systems, such as that of Brazil, the dominance of low activity clay soils in the intertropical zone has been recognized and mapped at a much higher categorical level. This, too, seems a reason to upgrade the particular diagnostic characteristic under discussion.

--<u>management</u>: the dominace of low activity clays in so many soils of the tropics has a profound influence on the management properties of these soils which, most commonly, are less favorable as regards the chemical and physico-chemical behavior of such soils.

The deliberations of the committee since its inception were mainly by correspondence. Opinions and proposals of the members were collated in a series of circular letters edited by the chairman. Personal contacts between a few members took place from time to time, but the Brazil workshop, reported here, offered the first occasion for discussions between a larger section of the committee participants, and for a confrontation of individual and group opinions during the study of relevant pedons in the field.

The present report attempts to summarize the discussions, dealing both with items on which a reasonable consensus of opinion could be reached and with items which remain, as yet, controversial.

B. Summary of Discussions

1. Level of Classification in Soil Taxonomy

The present level allowing distinction of Alfisols and Ultisols dominatd by low activity clays is the subgroup. In a number of great groups no further distinction is foreseen except at the family level for clayey pedons. In the committee's circular letters, the trend has been to upgrade these taxa to the great group level, using the prefix "Kandi" (from kandites, 1:1 lattice clays) in the nomeclature, as in Kandiudalf, Kandiustult, etc.

A leading argument for placement at this level is that the changes required, both as regards the overall structure of Soil Taxonomy and in terms of (re-)definition of existing and new taxa, would be kept to a minimum. The suborder level, which uses criteria mainly based on soil moisture regime (except for Boralfs and Humults), was found to be less suitable because at this level a two-way split of most existing suborders would be required except for Boralfs, Xeralfs, and Xerults. Alternative proposals, more or less well documented, include:

a. Introduction of a new order, characterized by low activity clays. An order of this kind would not only include the Kandi Alfisols and Ultisols, but also the oxic subgroups of other orders, e.g., Inceptisols and Mollisols, as well as the present Oxisols. In this proposal, the diagnostic criteria for orders of the present scheme (as the presence of a mollic epipedon combined with a high base saturation; the presence of argillic, cambic, oxic horizons; base saturation; and the soil moisture regime as in Aridisols) would have to be relegated to a lower category level. This proposal would require a complete reorganization of Soil Taxonomy.

The proposal would approximate the French approach as regards classification for soils of the tropics. The soils in the "low-activity-clay order" would be mainly the Ferrallitic Soils, but would include part of the soils of other classes, such as certain Ferruginous Tropical Soils and Hydromorphic Soils. Moreover, this order would fit in the new approach to soils classification of P. Segalen, where the mineralogical soil constituents are determinant at the highest categorical level.

b. Change of definition of Alfisols and Ultisols. Two variants with respect to this proposal were discussed:

--To define Alfisols and Ultisols as soils with an argillic horizon, as in *Soil Taxonomy*, but with, respectively, a dominance of high and low activity clays. The present criterion for distinction based on base saturation would be dropped at the order level. This proposal was previously discussed in the early circular letters as presented by C. Sys (Ghent). It is also the basis of the present classification in Brazil, where soils with an argillic horizon and dominated by low activity clays are grouped as Red-Yellow Podzolic Soils which are subdivided in eutrophic and dystrophic groups according to base saturation.

--To exclude from the Alfisols, as defined at present, all soils dominated by low activity clays. Such soils would become Ultisols, which order would therefore contain soils with high activity clays and low base saturation as well as soils with low activity clays irrespective of base saturation.

Both proposals have adherents among the committee members. Both, however, require considerable changes in the present *Soil Taxonomy*, and regrouping and revision of the existing taxa. A key question in this respect is which of the two properties, base saturation or clay activity, is the more meaningful one in terms of implied management properties and genetic soil development.

Moreover, some other points which require an answer are: which of the two properties can be defined with greatest precision, based on analytical work, and which of the two properties gives the best geographic-taxonomic separation of the pedons for which sufficient data are available.

In summary, the upgrading of Alfisols and Ultisols with low activity clays can be made at different categorical levels. The introduction of a new order incorporating all soils with low activity clays, irrespective of their present classification, would require a major overhaul and rewriting of Soil Taxonomy. The proposals for changing the present order definitions and grouping all Kandi soils with Ultisols would also require important revision, but should be further studied. The proposal to introduce the low activity clay property at the great group level, though requiring the least changes, is believed by part of the discussants to be insufficient in terms of taxonomic-genetic importance of this property.

The SCS, responsible for eventual introduction of modifications, generally requires that changes must accommodate the soils considered, but should affect others least. Thus, changes should be tested first at lower levels and only if this is not satisfactory, higher category changes should be proposed. Obviously, this philosophy favors the changes we are concerned with to be kept at the great group level.

2. The Argillic Horizon as a Diagnostic Property

In the correspondence, which was dealt with in various circular letters, a recurrent theme of discussion has been the definitions and the diagnosis of argillic horizons as one of the principal diagnostic properties in Alfisols and Ultisols.

In many soils with a kaolinitic-sesquioxidic clay mineralogy, the diagnosis based on the properties as set forth in Soil Taxonomy (pp. 19-27) is difficult. Clay skins in such soils are frequently difficult to diagnose in the field. In micromorphological studies, the shiny coatings are often found to be stress-cutans rather than oriented-clay argillans.

Determination of clay content in many of these soils is often problematic due to poor dispersion properties which diminishes the diagnostic value of the clay ratio between the alleged illuvial and eluvial horizons as a determinant for the presence of an argillic horizon.

In many of these soils, the B horizon satisfies the chemical and mineralogical properties of an oxic horizon; but they cannot be called Oxisols due to the presence of a "textural" argillic horizon, with or without clay skins. Thus, in the field, distinction between Oxisols and low activity clay Alfisols/Ultisols may become vague and rather arbitrary.

Possible solutions to the problems which these poorly expressed argillic horizons pose for the taxonomic classification include, according to R. Isbell (Australia):

--widen the definition of Oxisols by admitting an argillic horizon, and

--widen the required clay ration between A and B if no or no distinct clay skins or oriented clay are observable.

The loss of clay from the upper horizons does not necessarily result in an accumulation in the underlaying horizons. Lateral selective erosion of the fine fraction, clay breakdown by, e.g., ferrolysis and the process of "appauvrissement" recognized by the French (e.g., vertical clay movement without concurrent accumulation) can result in a texturally differentiated profile, without a clear process of accumulation as specified in Soil Taxonomy.

While such alternative processes leading to a textural differentiation are not specified in Soil Taxonomy, part of the discussants were of the opinion that the morphologically easily recognizable clay increase form A to B should be the norm. The clay ration requirement of the Soil Taxonomy definition (p. 27) may be increased for those soils where clay skins are not easily recognized in the field. A ratio of 1.4 for such soils with 15-40 percent clay in the eluvial horizon (p. 21) and corresponding values for more sandy and more clayey soils was proposed but not unanimously accepted.

A proposal was made to fill the gap between the oxic horizon and the well developed argillic horizon by introducing a "lixic" or luvic" horizon (Sombroek). This horizon is discussed below.

3. The "Thin Oxic Horizon"

In conjunction with discussions of the argillic horizon, difficulties arising from the presence of a "thin oxic" horizon were mentioned. In the current definitions, the presence of an oxic horizon of more than 30 cm is sufficient to classify a soil as an Oxisol. In many of the soils with a Pale clay distribution, the upper part of the argillic horizon has all properties of an oxic horizon. This is especially true in Paleudults and may occur even when a distinct A2 or E horizon is present. It was the opinion of most discussants that in cases where a thin oxic horizon is underlain by an argillic horizon with distinct clay skins, the depth requirement of the oxic horizon for classifying such pedons as Oxisols should be increased. It is proposed that the thickness of the oxic horizon should be 50 or 60 cm, and that no clear cutans should occur above 100 or 125 cm. The definition of Oxisols should be amended in this respect, as well as the pertaining section of the definition of Ultisols and, possibly, of Alfisols.

4. Diagnostic Properties of Kandi Taxa

These properties were discussed on the assumption that the low activity clay properties in Alfisols and Ultisols will be distinguished at the great group level (see A.). For distinction at a higher level, most but not all of these diagnostic properties would retain their validity.

a. Soil temperature regime. While Kandi Alfisols and Ultisols are most widespread in the humid and subhumid tropical zone, they are not exclusively tropical; important surfaces occur in the warm temperate zones. It is recommended that the soil temperature regime should not be a diagnostic criterion in the definition of the Kandi taxa, as distinct from the Trop taxa.

b. Cation Exchange Capacity (CEC). In the original proposal for Kandi great groups, the CEC value diagnostic for the present Oxic subgroups in Soil Taxonomy was recommended, i.e. less than 24 meq/100 g clay by NH_4OAc (determination 5A1a, USDA-Soil Survey Investigation Report No. 1, 1972) and a cation retention capacity from NH_4Cl of less than 12 meq/100 g clay. In correspondence, referring to the circular letters of the committee and to the discussions during this workshop, the difficulties in the determination and the lack of precision of this criterion were highlighted. In materials dominated by low activity clays, the permanent charge is low relative to the pH-dependent charge, while the total charge is low. The consequence is, among others, that slight aberrations in determination may lead to considerable divergence of values, both for CEC and for the related value of base saturation. Physico-chemical aspects of the CEC determination were discussed during the workshop. An alternate value to be used as a diagnostic characteristic can be the ECEC, i.e. the sum of cations plus exchangeable Al and H, as determined at the pH of the soil. Correlation between NH_4OAc CEC at pH 7 and ECEC are mostly significant at the low CEC values in questions where soils with a similar clay minerology are considered so that both values may be used, provided that correlations are established in "benchmark" profiles.

Whereas the NH_4OAc method is in widest use and because no inherently superior methods are available for determining clay activity as a diagnostic taxonomic criterion no changes in the present definition of Oxic subgroups can be proposed. For the present report the CEC by NH_4OAc at pH 7/100 g clay is maintained unless mentioned otherwise.

Accessory properties would pertain to characteristics such as structure (weak), consistency, etc. A distinct disadvantage of introducing such an "intermediate" horizon would be that two sets of differentiating properties will have to be defined instead of the present single set. While most of these properties are difficult to pin down in the field it is not certain whether the introduction of the luvic horizon would be an advantage.

For the diagnostic value of CEC of Kandi great groups, several alternative were discussed:

a. Maintain the limit of 24 meq, as in the present Oxic subgroups.
b. Introduce the limit of 16 meq, parallel to the value used for defining an oxic horizon (Soil Taxonomy, p. 39), and use the range of 16-24 meq for defining "Kandic" subgroups.
c. Use both 16 and 24 meq as a break; for example 16 meq for Ultisols and 24 meq for Alfisols.
d. Use a single value, intermediate between 16 and 24 meq, e.g. 18.

Solution (a) would require least changes, but has as the disadvantage that 2:1 lattice clays could be present in the clay fraction in measurable quantity. North Carolina research showed that 10 percent montmorillonite in the (kaolinitic) clay fraction would cause the CEC to be 18 meq or higher, which would considerably change engineering properties of the soils, e.g. in respect to septic tank construction (S. Buol). Solution (b) would cause the Kandi great group to be more pure in the sense that admixture of 2:1 lattice clays would be negligible in most cases. A disadvantage would be that for certain soil regions, especially in low activity clay Alfisol areas, the Kandi groups and subgroups would be intricately mixed. For that reason, solution (c) may be preferable as was found in studies in Nigeria (F. Moormann). Solution (d) is supported by North Carolina data, but insufficient information is available from elsewhere.

The use and usefulness of ECEC as a diagnostic tool was discussed. Preliminary research seems to indicate that the value of 14 meq/100 g clay would separate the low activity clays from those which have a measurable admixture of 2:1 lattice clays with a higher activity. Part of the discussants would prefer ECEC as the standard for separation of the Kandi groups and the Kandic subgroup. An NH_4OAc-CEC/100 g clay of 16 meq would correspond approximately with an ECEC of 12, while 24 meq would give an ECEC of about 18 meq in soils from Puerto Rico (Eswaran). Other but similar values are found in other areas with variations according to parent material, pH, base saturation, and, possibly, other parameters. A possible solution is to use ECEC instead of the cation retention capacity from NH_4Cl, and change the definition of Kandi, and Kandic as follows: "have CEC of more than 16 (resp. 24) meq/100 g clay (by NH_4OAc) or an ECEC of 12 (resp. 18)/100 g clay."

The word "or" is underlined, and would replace "and" in the present definition. While this alternate choice would weaken the precision of the definition, the number of cases in which low activity clays according to the NH_4OAc CEC would become high activity clays according to ECEC or vice versa is probably low. Correlations found in the literature between the two values and provided in the framework of the committee's work are mostly good to excellent. In practical terms the main advantage of ECEC is that this analysis is uncomplicated and well reproducible; contrary to the NH_4OAc CEC determination.

Besides these two types of CEC determination, other analytical procedures are used in various countries. Such other data are not directly usable in the "translation" of various national classifications into Soil Taxonomy units. In order to do so, correlation between the "national" analyses and NH_4OAc CEC and ECEC should be made on a sufficient number of samples. Work in Brazil (see circular letter no. 8, appendix 5) may serve as an example in this respect.

In Soil Taxonomy the diagnostic CEC values are measured on the whole soil and include the CEC of organic matter which is essentially determined by pH dependent charges. In the Brazil classification, the diagnostic CEC is determined on the mineral fraction. The Soil Taxonomy approach leads to considerably higher CEC/100 g clay values in soils where the C content of the argillic horizon is high, e.g. in many Humults and/or where the clay content is low (coarse loamy or coarser families) so that the contribution of the CEC of organic matter is relatively high. In other cases, the contribution of organic matter to the CEC of the argillic horizon is relatively unimportant. Further studies are required to show whether the CEC of the mineral fraction is preferable to the CEC of the total soil. A priori, for low activity clays, the CEC of the mineral fraction seems to be a better diagnostic value.

The diagnostic depth of the argillic horizon, or its substitute, dominated by low activity clay was generally accepted to be the upper 50 cm of this horizon. The weighted average CEC of this layer is determinant. It should be noted, however, that a relatively sandy and/or humiferous Blt horizon may increase the level of the weighted average CEC, unless the CEC of the organic matter is discounted, as is done in the Brazilian system of soil classification. In this case, the decrease of the clay CEC in the lower horizons with less organic C should be taken into account.

C. Weatherable minerals (as listed in Soil Taxomony, p. 64). A point of discussion was if taxa with "Kandi" characteristics should be required to have less than 10 percent weatherable minerals in the 20-200 micron fraction. The present situation is that this requirement does not occur in Alfisols, only in the Pale great groups of Ultisols, i.e. Paleaquults, Palehumults, Paleudults, Paleustults, and Palexerults.

For great groups in Ultisols, which key out after the Pale great groups, the content of weatherable minerals is not an exclusive characteristic but is linked with the textural profile, e.g.: Tropudults (p. 367) have either or both a) a "non-Pale" clay distribution and b) more than 10 percent weatherable minerals in the 20-200 micron fraction. Thus, these great groups may have a low content of weatherable minerals, provided that the percentage of clay decreases from its maximum amount by more than 20 percent within 1.5 m from the soil surface.

The present Oxic subgroups, which are mainly the precursors of the Kandi great groups, and subgroups, do not need to have a low content of weatherable minerals in the 20-200 micron fraction. This trend in Soil Taxonomy appears contrary to the general assumption in the literature (e.g. the French definition of Ferrallitic Soils, CPCS 1967), whereby dominance of low activity clays and lack of weatherable minerals in the sand fractions are given as linked properties. Recent research, e.g. in Southern Nigeria by IITA, favors the Soil Taxonomy principles.

While it is true that in most Kandi soils, especially those on parent materials derived from sedimentary rocks poor in such minerals, the properties "low activity clay" and "low content of weatherable minerals in the 20-200 micron fraction" coincide, exceptions are found. Soils derived from weathered crystalline rocks, mainly in the intermediate range, such as granites and gneisses, may have a dominantly kaolinitic clay mineralogy while at the same time the amount of weatherable minerals in the coarser fraction may be well above the limit of 10 percent.

It may be concluded that the possible diagnostic property of "less than 10 percent weatherable minerals in the 20-200 micron fraction in the upper 50 cm of the argillic horizon" is controversial and should not be introduced "across the board" in the Kandi taxa. For Alfisols, where this property is not diagnostic above the family level, it appears that its introduction is undesirable. For Ultisols, the present diagnostic use of the criterion for the existing Pale great groups may be followed, which would mean that Kandi groups in all suborders would be required to have a low content of weatherable minerals in the upper 50 cm of the argillic horizon. The consequences of this, however, have to be tested.

The discussions on the subject indicate that at present no general opinion can be presented, there being few firm data available. A more general concensus was reached regarding the presence of muscovite-micas. Especially in soils derived from crystalline rocks, but also in some which developed on micaceous sedimentary materials, amounts of muscovite-micas in excess of 10 percent can be present in the 20-200 micron fraction. Because most forms of muscovite present in soils should be classified as slowly weatherable minerals, it is agreed that a higher content of this mineral should be classified as slowly weatherable minerals, it is agreed that a higher content of this mineral should be admitted in soil materials of Kandi taxa characterized by a low content of weatherable minerals. No specific upper limit was proposed.

5. Content in the Clay Fraction of Non-Crystalline Hydrous Oxides and Specific Surface Area

Attention was given to soils with high content of Fe hydrous oxides. These soils are mainly (but not exclusively) developed from parent materials rich in dark-colored minerals such as hornblende, amphioles, augite, and biotite. Soils on most basalts and gabbros, with low value colors which are mostly reddish, are in this category.

At present, Soil Taxonomy provides no specific taxa for such soils, unless at the family level (oxidic, subs, ferritic families). A considerable proportion of these soils belong to Rhodic taxa, with separation either at the great group or the subgroup level. The definition of the Rhodic property is, however, strictly on soil color and not on the mineralogical composition of the clay fraction.

Soils with a high content of Fe oxides with a high specific surface area and dominance of low activity clays have pedological and edaphological characteristics which clearly set them apart from Kandi groups developed from more acidic parent materials, e.g. higher structural stability, lower erodability, and better moisture characteristics. Comparatively, these soils are better in terms of production, both of perennial and of most annual foodcrops, in tropical and subtropical regions. A possible diagnostic characteristic is the high specific surface area of the (clay) fraction, but the determination is difficult and costly and cannot be expected to be introduced as a routine analysis in most service laboratories.

The general opinion was that these soils should be separated, if possible at the great group level, from the Kandi taxa. The behavior of the soil material in respect to soil silica (silica sorption/desorption) may possibly be used (Juo, Herbillion). These determinations have, however, been tested on too few pedons to recommend at the present time their use for separating these soils at a higher categorical level. Further research on the subject is necessary though it is clear that the present exclusive color differentiae for the Rhod great groups and subgroups is not sufficient to obtain a satisfactory separation of these soils, which are mainly formed on parent materials from their basic rocks high in ferro-magnesium minerals.

6. The Place of Kandi Great Groups of Alfisols and Ultisols in the keys of Soil Taxonomy

While the place of the Kandi taxa in the great groups will be variable according to the suborders, the general opinion was in favor to give a high priority to these great groups. Most attention, both in the circular letters and in the workshop discussions, was given up to now to keying out the Kandi great group in Udults, and to a lesser extent in Ustalfs, based on work in W. Africa.

a. Relationship of Plinth and Kandi great groups. Many, but certainly not all, pedons with plinthite that key out as a Plinth great group are dominated by low activity clays. Therefore, if the presence of such plinthite is to have priority over the Kandi characteristic in the keys, provision may have to be made for distinction at the subgroup level of low and high activity clay dominance in the Plinth great groups. Low activity of the clay would most probably have to become a diagnostic property of the Typic subgroup.

   In case the Kandi characteristics would be given priority over the presence of plinthite, provision would have to be made at a subgroup level in the Kandi taxa for the presence of plinthite. There would be two subgroups required:

   --one with plinthite that constitutes more than half the matrix of some subhorizon in the upper 1.25 m of the soil, and

   --one that has a subhorizon within 1.5 m of the soil surface that has more than 5 percent but less than 50 percent plinthite.

   A third possible solution is to relegate the presense of plinthite to a lower level in the classification, i.e. the subgroup level. There are arguments in favor of cancelling the Plinth great groups, one of them being that the presence of plinthite does not seem to negatively influence root growth, as is the case in soils with a fragipan. Plinthite at the subgroup could be dealt with in conjunction with the hardened forms (petroplinthite or lithoplinthite, and petroferric).

The discussion on the importance of plinthite in Soil Taxonomy is as yet incomplete. Further study is needed in tropical areas; in the U.S. only two series were found in Plinth great groups.

b. Relationship of Pale and Kandi great groups. The initial trend in the committee was to key out the Kandi great groups before the Pale great groups in those suborders where Pale taxa occur. A general rule could, however, not be worked out in view of the varying diagnostic sets of properties for the different Pale taxa.

In Alfisols, Kandi taxa can keyed out before Pale taxa without affecting too many established series especially because Paleudalfs are excluded from the intertropical zone with an iso-soil temperature regime. The main taxon affected is that of Oxic Paleustalfs which occur over considerable areas, e.g. in W. Africa.

As regards the kind of soils grouped under Paleustalfs and Palexeralfs, several discussants pointed out that the inclusion of soils characterized only by an abruptic upper boundary of the argillic horizon is not satisfactory (see Soil Taxonomy, p. 142, definition 3 c, and p. 151, definition 1 d). For Ultisols, the Kandi great groups can be keyed out before the Pale great groups, but the consequences are more far-reaching than in the case of Alfisols.

Only in the Palehumult great group are oxic subgroups foreseen, which means that at present no distinction is made at any level above that of the family between, e.g., Paleudults with high activity clays and Paleudults with low activity clays. Smith has already proposed Oxic subgroups for the Paleudults, based on data from soils in Zaire. In the context of the present Soil Taxonomy, the need for such Oxic or low activity clay taxa was felt appropriate for the other suborders as well.

The keying out of the Kandi great group prior to the Pale great group in Udults has, however, an undesirable effect in such areas where virtually only Udults dominated by low activity clays occur. In Malaysia, for instance, most freely drained low activity clay Ultisols, at present belonging to three great groups (Paleudults, Rhodudults, and Hapludults), would have to be united in one great group of Kandiudults. Therefore, at least as regards Udults, the desirability and feasibility of keying out the Pale great group before the Kandi great group should be further explored.

e. Relationships to Trop and Kandi great groups. Trop great groups in Soil Taxonomy are mainly used to differentiate taxa that have an isomesic or warmer iso climate, and that do not belong to other great groups such as Pale, Plinth, etc. Moreover, no Trop great groups have been introduced in suborders with an ustic or xeric soil moisture regime, with the possible exception of the Humult suborder. Trop great groups were introduced on the specific suggestion of European pedologists working in the tropical zone of Africa (G. Smith). As pointed out by several committee members, the Trop notion is neither very useful nor does it give satisfactory taxonomic and cartographic information. Thus, for instance, Paleudults and Tropudults may occur side by side in almost identical physiographic and environmental conditions. Moreover, and this is particularly true for S. America, the border between Trop great groups and great groups which do not have an iso-soil temperature regime may be very difficult to establish.

Kandi great groups will key out before Trop great groups in all suborders. Because most Trop pedons in the intertropical zone are dominated by low activity clays the extent and relevance of the Trop great groups would be further diminished.

7. Subgroups of the Kandi Great Groups

Few general rules for defining subgroups can be made; those rules vary between orders or even between suborders. Moreover, not enough firm data are available to envisage at this time anything more than a sketchy and preliminary listing of subgroups. Even the definition of the Typic subgroup will depend on the place to which the Kandi taxa will be assigned in the keys. Thus, while there was a fairly general concensus that the Typic in the Kandi taxa should be soils with a deep Pale argillic horizon, this rule cannot be generalized if, in the Udult suborder, the Pale great group would be keyed out prior to the Kandi great group (see F.1.). However, if it is assumed that the Kandi great groups would have priority over Pale and Trop great groups, a general characteristic of the Typic subgroup would be as follows:

"have a clay distribution such that the percentage of clay does not decrease by more than 20 percent of that maximum within 1.5 m of the soil surface, or the layer in which the percentage of clay is less than the maximum has skeletans on ped surfaces or has 5 percent or more plinthite by volume."

This requirement of the Typic subgroup would lead to the general introduction of a "thin subgroup," either with a lithic, paralithic, or petroferric contact at less than 150 cm from the surface or with a clay content in the argillic horizon diminishing by more than 20 percent from its maximum at less than 150 cm depth, and there should be no distinct clay skins in the layers with less clay at a depth of 150 cm. Preliminary this thin subgroup would be called Leptic.

Most subgroups occurring under Kandi taxa have their parallels in other great groups. Thus, subgroups like Aquic, Arenic, Grassarenic, Spodic, etc. can be "borrowed" from other taxa and defined accordingly. Some subgroups may be required which are specific for the Kandi taxa, but extensive testing is required.

In the Kandi taxa of Alfisols, of which a fairly extensive study was made in W. Africa (mainly Ustalfs), there is a distinct need to separate Kandiustalfs with a high content of weatherable minerals from those where this level is distinctly less that 10 percent. The former are mainly developed on parent materials derived from weathered crystalline rocks; the latter are from arenaceous sedimentary materials, and have the type of pedon which falls under the notion of "appauvri" of the French literature. It may be proposed that a content of less than 10 percent weatherable minerals would be a requirement of the Kandi taxa in Alfisols, while those containing more than 10 percent would become a separate subgroup for which at present no name is proposed. In the Kandi taxa of Ultisols, most attention during this workshop was given to Udults.

The following tentative requirements were presented:

--A separation between Kandidults with a high Al saturation (Al^{3+}/Al^{3+} + sum of bases x 100 more than 50 (?)) and those with a low saturation. High Al saturation (i.e. the "Alic" taxa of the Brazilian classification) may be proposed as a requirement for the Typic subgroup. No nomenclature was proposed for the subgroup with low Al saturation.

--Distinction of a subgroup with very low CEC/100 g clay values, parallel to the Acri great groups in Oxisols. A tentative definition of an Acric subgroup would include: ECEC of less than 5 meq/100 g clay in the major part of the argillic horizon and exchangeable Al constant or diminishing with depth. The diagnostic value of 5 meq should be tested and may well be too high.

--Distinction of a subgroup with characteristics, similar to the present Epiaquic subgroups, i.e. mottling in the lower part of the A and the upper part of the argillic horizon. The possible nomenclature for such soils with superficial mottling may be "Planic" (Beinroth).

--Distinction of a subgroup with distinct reticulate mottling without the low-chroma colors required for aquic, and without the hardening upon exposure to alternate drying and wetting required for plinthite. The possible nomeclature for the subgroup would be "Ferric." This term has a similar connotation in the FAO-Unesco Legend (Ferric Acrisols).

II. Thailand Workshop

Taxonomic Problems of Low Activity Clay Alfisols and Ultisols*

F. R. Moormann

A. Introduction

Soils dominated by low activity clays (LACs), i.e. clays of the kandite (kaolinite) group with or without an admixture of considerable proportions of ferric oxides, have received relatively scant attention in the present Soil Taxonomy. This is acceptable in the context of the mandate of Soil Taxonomy (preface) as a classification system for soils in the U.S., Puerto Rico, and the Windward Islands. However, when applying the classification system to other regions of the world, specific limitations become apparent. In particular in tropical and some subtropical regions, soils dominated by low activity clays abound. In the present Soil Taxonomy system, this soil property is catered to at three levels:

--At the order level where a diagnostic characteristic of Oxisols is the dominance of low activity clays in the oxic horizon (see summary of properties of the oxic horizon, Soil Taxonomy, p. 39);

--At the subgroup level where the oxic subgroups of Inceptisols (but not Andepts), Mollisols, Alfisols, and Ultisols have--in horizons specified according to the order--a cation exchange capacity (CEC)/100 g clay (by NH_4OAc) of less than 24 meq and a cation retention capacity from NH_4Cl of less than 12 meq/100 g clay; and

--At the family level where the dominance of low activity clays can be indicated by the mineralogy class, but not if it concerns soils with coarse particle size classes.

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The level at which taxa dominated by low activity clays, other than Oxisols, can be distinguished appears too low for a meaningful taxonomic classification for most tropical and some subtropical soils. Geographically certain subgroups may have a very wide distribution, e.g. Oxic Paleustalfs. Taxonomically such oxic subgroups often combine widely divergent (poly)pedons which merit distinction at a level higher than that of the family or series. The management properties of soils are often more closely linked with the specific mineralogical composition of the clay fraction than with almost any other diagnostic property.

The International Committee on Classification of (Alfisols and Ultisols with) Low Activity Clay Soils (ICOMLAC) was charged to work out recommendations for the upgrading in Soil Taxonomy of the present and possible oxic subgroups belonging to the two orders mentioned. Oxic subgroups of Inceptisols and Mollisols will be dealt with at a later stage, but their classification can be expected to follow rules recommended by ICOMLAC. Implied in the ICOMLAC mandate is the requirement that the present structure of Soil Taxonomy should be changed as little as possible and only when a more meaningful grouping of LAC soils is required.

B. Problems of Classification

In its endeavor to upgrade the categorical level of LAC Alfisols and Ultisols, the following main taxonomic problems were topics for international discussions.

1. The argillic horizon

   The presence of an argillic horizon, as described in Soil Taxonomy, is a main diagnostic property of Alfisols and Ultisols. Discussions covering a wide range of topics included:

   a. The pedogenetic significance of the argillic horizon, whereby the basis for classification of LAC-dominated soils according to Soil Taxonomy was challenged;

b. The properties (clay increase from the epipedon downward, and the presence of clay skins) used to diagnose an argillic horizon by field observation and by supporting laboratory and micromorphological data, notably:

(1) The absence or near absence of clay skins in many LAC Alfisols and Ultisols, most often in Udults of perudic tropical areas with a kaolinitic-ferri(hydr)oxidic clay mineralogy, but also in other taxa. The boundary between many LAC Ultisols and Oxisols is very vague;

(2) The interpretation of a clay increase from the epipedon downward which, apart from eluviation-illuviation as in a "true" argillic horizon, may be caused by lateral removal of the clay fraction (as in slowly eroding soils), by clay breakdown in the epipedon (as in soils subject to ferrolysis), or by depositional layering;

(3) The presence and the maximum admissible thickness in Alfisols and Ultisols of a horizon with properties of an oxic horizon, overlying a "distinct" argillic horizon;

(4) The magnitude of a clay increase from A to B and the maximum vertical distance within which this clay increase should take place for the finer textured subsurface horizon to be considered as an argillic horizon.

c. The wide variation in nature and field appearance of argillic horizons, and the desirability and feasibility of subdividing such a horizon or "endopedon" according to characteristics (structure, bulk density, etc.) other than just clay increase ratios and the presence of clay skins.

2. Classification level for LAC soils

The present level of distinction of LAC Alfisols and Ultisols in Soil Taxonomy is the subgroup ("oxic" subgroups) and in a number of cases, the family. In several cases, the dominance of LAC soils is implied in the taxa definitions, but no specific LAC taxa are distinguished. This is the case in the great groups of Udults where at present no oxic subgroups are foreseen (except in Tropudults). Alternatively, in the suborder of Humults most great groups have oxic subgroups.

The trend of the discussions has been to upgrade distinction of all LAC Alfisols and Ultisols to the great group level by introduction, where appropriate, of kandi great groups under the existing suborders. No kandi great groups were proposed for the suborders of Boralfs, Xeralfs, and Xerults; but the possibility for kandi taxa in the latter two suborders must remain open if such pedons were found, mapped, described, and analyzed.

The possibility of distinguishing the kandi properties of all LAC soils (except Oxisols) at higher categorical levels was discussed and studied. Such high level upgrading, though having attractive aspects (e.g. closer relations with existing national and international classification systems), would mean a considerable change in the present structure of Soil Taxonomy. Assuming the classification of kandi properties of Alfisols and Ultisols at the great group level, a point of discussion was the ranking to be given to the kandi taxa in the great group keys. Especially as regards the existing plinth great groups (often dominated by LAC pedons), the ranking of the kandi great groups poses problems. Though not strictly included in the mandate of ICOMLAC, a point of discussion was (is) the relevancy of trop taxa in the higher categories of Soil Taxonomy.

3. Diagnostic properties of Kandi taxa

Central to the discussions of diagnostic properties to distinguish kandi taxa from the others in Alfisols and Ultisols is the question of CEC and cation retention properties. In the first instance it was thought to adopt the present boundary of the oxic subgroup as the boundary of the kandi great groups. For oxic subgroups, the requirement is that they should have a CEC of less than 24 meq/100 g clay by NH_4OAc at pH 7 and a cation retention by NH_4Cl less than 12 meq/100 g clay.

Points of contention and discussion on this requirement were:

a. Should the 24 meq boundary be maintained or should it be lowered to 16 (as for Oxisols) for all or part of the kandi taxa belonging to Ultisols. If the limit is lowered to 16 meq, should kandic subgroups be introduced to cover those pedons now belonging to oxic subgroups and having a CEC of less than 24 meq but more than 16 meq.

b. Is the cation retention by NH_4Cl a relevant measure or should it be replaced by ECEC (sum of cations + exchangeable Al and H, by 1N KCl extraction at the pH of the soil). If so, what is the relevant diagnostic level of ECEC. Also, should ECEC be an alternate criterion to the CEC by NH_4OAc or an additional one.

c. What is the diagnostic depth of the CEC and/or the ECEC, e.g. the upper 50 cm of an argillic horizon.

d. Should CEC and ECEC be determined on the whole soil or, as in Brazil, on the soil with exclusion of organic matter.

e. In view of the difficulties in obtaining reproducible data with the present methods of CEC/ECEC determination, can other methods to determine charge properties be found, tested, and recommended for taxonomic purposes? Also, can relevant accessory field and laboratory measures be identified which can help to better characterize LAC taxa.

f. How can we accommodate in a revision of Soil Taxonomy those pedons in which the surface charge of the clay fraction is mainly of the constant surface potential (or pH dependent) type. Collateral to this question: should the presence of considerable contents of "active" Fe (hydr)oxides (with an important specific surface and a dominance of constant surface potential) be recognized at the great group level, parallel with but separate from the kandi taxa. The pedons involved are mainly those developed on basic and ultrabasic materials.

g. In general, we are only in the early stages of study and recognition of properties of "low activity clays," and further efforts are required to "translate" the research data of soil chemists and mineralogists into usable taxonomic criteria.

Discussions pertained also to the significance and role of weatherable minerals, defined according to Soil Taxonomy, in the distinction of kandi taxa of Ultisols. Data available indicate that the dominance of kaolinite-sesquioxide clay systems does not necessarily go together with a low level of weatherable minerals, as has been generally assumed in the literature on soils of the tropics. Hence, the relevance of a low content of weatherable minerals to distinguish kandi taxa from other Alfisols and Ultisols was seriously queried. Especially, the presence of muscovite in considerable quantities (more than 10 percent) seems irrelevant in regard to the (presumed) degree of weathering of soils. Muscovite is, in many cases, less weatherable and can occur in measurable quantities even in pedons which for all practical purposes should be classified as Oxisols. A review of the diagnostic characteristic "weatherable minerals" is deemed necessary.

C. Subgroups in Kandi Taxa

1. Typic versus leptic subgroups

An original premise of ICOMLAC was that by upgrading present and possible oxic subgroups to the kandi great group level, more room would be created for introducing relevant subgroups without the necessity for double or even triple subgroup names. In this concept, the typic subgroups of kandi taxa would have a clay distribution of the argillic horizon such that the clay content does not decrease more than 20 percent from its maximum at 150 cm, or clay skins are present at that depth. Kandi pedons with a thinner argillic horizon, or with a lithic, paralithic, or petroferric contact at less than 150 cm depth, would belong to leptic subgroups.

The disadvantage of "lumping" all LAC pedons into a single kandi taxa, irrespective of the depth of the argillic horizon, became clear for countries such as Malaysia where virtually all Ultisols (Udults) are dominated by low activity clays. Here, the present distinction between Paleudults and Tropudults would disappear at the great group level. Similarly, for other Udult areas, as in the southeastern United States, no distinction at the great group level would be possible between LAC Paleudults and Hapludults. "Lumping" then would also occur in other taxa: Oxic Paleustalfs and Oxic Haplustalfs, for instance, would become respectively, Typic Kandiustalfs and Leptic Haplustalfs. Apparently, the simple "lumping" of all oxic subgroups into one kandi great group will diminish the taxonomic usefulness of the kandi distinction, and it appears necessary to introduce two parallel kandi great groups per suborder, i.e. a deep one with characteristics parallel to the present pale great groups, and a "shallow" one, which would accommodate the present oxic subgroups of mainly the trop, rhod, and hapl great groups.

2. Subgroup with very low activity clay

In certain kandi pedons, especially of Udults, a very low CEC or ECEC of the clay fraction occurs. The introduction in Oxisols of a relevant subgroup, parallel to the present acr great groups, was discussed. If so, the diagnostic ECEC value for 100 g clay should be chosen and tested. A proposal was made for the acric subgroup to have an ECEC of less than 5 meq/100 g clay in the major part of the argillic horizon, but this value may be too high.

3. Subgroup with very low base saturation

The necessity was discussed for the introduction of a subgroup with very low base saturation or, alternately, with high Al^{3+} saturation. The difficulty is to agree on the diagnostic depth of such a very low base saturation or high Al^{3+} saturation. Because it is a characteristic of the upper part of the profile subject to change, e.g. by liming, a greater diagnostic depth would be required. In such cases, however, this subgroup would become taxonomically less meaningful.

4. Other Subgroups

Other possible subgroups not specific for kandi taxa, but possibly more frequent in such taxa than in other Alfisols and Ultisols, were tentatively discussed. These included soils with characteristics similar to the present epiaquic subgroups, and also soils with strong reticulate mottling ("mottled clay") that do not harden upon drying (like plinthite) and are therefore not indicative of an aquic moisture regime.

Not enough firm data are at hand to make a complete list of subgroups for the kandi taxa, though generally the existing lists of subgroups from related taxa in Soil Taxonomy can be used. Subgroups that will occur in various kandi great groups include: aquic, arenic, grossarenic, rhodic, plinthic, psammentic, spodic, lithic, petroferric, or combinations of those "basic" subgroups.

III. Syria Workshop

Purpose, Mandate and Progress of ICOMLAC

F. R. Moormann

A. Introduction

The International Committee on Classification of (Alfisols and Ultisols with) Low Activity Clay Soils (ICOMLAC) was organized in 1975 by the Soil Conservation Service (SCS), USDA. Membership of the committee now stands at approximately forty, up from the original twenty "founding members," and includes experts on the soils of the inter-tropical zone from nineteen different countries. Contact between members is mainly by correspondence with the chairman and by circular letters. The twelve circular letters which were sent out up to 1 January 1980 reflect the difficulties encountered and the slow but steady progress made in fitting "new" soil taxa in the taxonomic framework of Soil Taxonomy. Much progress was made through personal contacts of committee members on various occasions, but more in particular during the First and Second International Soil Classification Workshops (Brazil 1977 and Malaysia-Thailand 1978). The proceedings of these workshops reflect the enormous amounts of work and know-how provided by the members of ICOMLAC, most of whom were invited to these discussions and field tours.

B. Purpose and Mandate of ICOMLAC

The preface of Soil Taxonomy states: "The classification is not equally developed in all parts. The classification of tropical soils...needs more testing."

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Recent soils surveys and related soil research in the intertropical areas has indeed emphasized the necessity for the introduction of additional soil taxa and for a review of the existing ones, including a further study of the differentiating criteria used for their definitions.

In the humid tropics (though not exclusively there), a large proportion of the soils show characteristics related to intensive and prolonged weathering. Generalizing, it can be stated that the high degree of weathering is reflected in the mineralogical composition of the clay fraction in these soils. This fraction is dominated by 1:1 layered clay minerals, in particular kaolinite, and by oxides and hydroxides of iron, with common occurrence of gibbsite, $Al(OH)_3$. Clays with such a composition have been given the generic name "low activity clays" whereby the term "low activity" pertains to the low CEC value at any pH value of the clay fraction in these highly weathered soils. Variable charge properties dominate the clay fraction and permanent charge clay minerals, such as smectites, are either rare or completely absent.

The dominance of low activity clays is used as a diagnostic criterion at several levels in Soil Taxonomy:

--At the order level, low CEC is implied in the definition of those Oxisols which have an oxic horizon, since one of the properties of the latter is a CEC by NH_4OAc at pH 7 of 16 meq/100 g clay, or less.

--At the subgroup level, those oxic subgroups with a CEC (NH_4OAc, pH 7) of 24 meq/100 g clay or less, in a specified part of the pedon, reflect the dominance of low activity clays. Oxic subgroups occur mainly in the Ultisol order, but are also defined in Alfisols, Inceptisols, and Mollisols. It should be pointed out that no oxic subgroups were recognized in the great groups of Hapludults and Paleudults because of the assumption that pedons of these taxa mostly would be dominated by LAC. Introduction of oxic subgroups in the Paleudults great group was proposed by G. Smith et al. (1975).

--At the family level, the mineralogy class (Soil Taxonomy, pp. 386-387) may be indicative, but the criteria are not specifically geared to recognize and classify pedons dominated by low activity clays. More specifically, for the non-clayey particle size classes, clay mineralogy of the <0.002 mm fraction is not diagnostic.

Essentially, therefore, apart from the Oxisol order, only the subgroup level is at present available for distinguishing and defining taxa in which the dominance of low activity clays is an important and measurable property. For reasons non-exhaustively listed below, this categorical level was deemed too low by workers involved with taxonomic classification in the intertropical zone:

--Genetically, the LAC property is extremely important because it reflects the "state of weathering" in the solum. This is so even though this soil property may be in part inherited from the parent material.

--Taxonomically, it appears that in the present oxic subgroups, more in particular those of Alfisols and Ultisols, many quite divergent pedons are grouped in one taxon, and Soil Taxonomy does not provide for further differentiation at a level above the family or even above the series. This leads to a confusing impression of the geographical distribution of "oxic" taxa, indicating a non-existing uniformity of soils in many areas of the tropics. Moreover, the number of taxa used to subdivide LAC soils stands in no relation to the possibility of subdivision of better known taxa in, e.g., the temperate region of the U.S.

--In terms of management-related properties the LAC soils greatly and fundamentally different from soils dominated by higher activity clays of the 2:1 lattice type. It seems unsatisfactory to leave distinction of these differences to such a lowly categorical level as the subgroup. The purpose of the work of ICOMLAC, therefore, is to remedy this imbalance of the present version of Soil Taxonomy. The mandate of ICOMLAC is to recommend to the SCS changes in the classification of Alfisols and Ultisols dominated by low activity clays, and to define such LAC taxa, as well as the diagnostic properties required for such definitions. It should be noted that the mandate is limited to the Alfisol and Ultisol orders; it is expected, however, that the proposed amendments will be valid for LAC taxa in other orders. Implied in the mandate is that amendments should "retain, as far as practical, the groupings currently used, and define the limits of each class as objectively and precisely as practical" (SCS, 1974).

C. Discussion of Progress Made

On first sight, it seemed relatively simple to achieve the goal outlined in the mandate of ICOMLAC. Indeed, in a number of taxa at the great group level in Alfisols and Ultisols, provision was made for "oxic" (orthoxic, ustoxic, etc.) subgroups. Thus, it appeared that all that was needed was the upgrading of these subgroups to a higher category in Soil Taxonomy, and the extension of these upgraded oxic subgroups to other taxa in Alfisols and Ultisols. However, in the course of the work of ICOMLAC, it became clear that various problems had to be solved and solutions agreed upon pertaining to matters which in Soil Taxonomy were (of necessity) dealt with incompletely.

The main groups of problems around which our study has centered are:
--level of classification of the LAC taxa in Alfisols and Ultisols, including nomenclature of the new taxa;
--diagnostic criteria to be used for delineating the proposed new taxa;
--relation to existing taxa in Soil Taxonomy and, hence, place in the keys of the new taxa; and
--subdivision of the new taxa at lower categorical level(s).
For the first three items mentioned, considerable progress has been made, which will be dealt with below. The fourth item is still very much under discussion and no complete proposals could (or can be) made in view of a lack of firm field and analytical data. Hence, only a tentative progress report can be given on this item.

1. Level of classification and nomenclature

Two levels above the subgroup were considered, i.e., order and great group. The diagnostic properties used for the suborder level (mainly soil climatic) clearly do not fit the requirements of ICOMLAC.

The distinction at the order level would either require creation of a new order, or the change of the definition of the Oxisol order in such a way that all pedons dominated by low activity clays could be incorporated in this order. Although this solution would seem advantageous from a soil-genetic and soil- mineralogical point of view (i.e. grouping of all soils with dominance of 1:1 lattice clays and/or (hydr)oxides of Fe and Al), it would clearly not fit the requirements of the mandate. Indeed, such amendments would require a complete overhaul of important portions of the present Soil Taxonomy and present groupings could not be retained, while the taxonomic advantages of such a placement of LAC pedons can be strongly queried. This severe disadvantage does not present itself if the LAC Alfisols and Ultisols are distinguished at the great group level, where from taxonomic, cartographic, soil management, and (to a certain extent) genetic viewpoints, the separation would be meaningful. It therefore was decided to use the great group level as appropriate to introduce LAC taxa in Alfisols and Ultisols.

The nomenclature proposed for these taxa is based on two formative elements (kandi and kanhaplo, 1:1 lattice clays). The connotation of these names is the relative importance of 1:1 lattice clays, and more specifically of kaolinite, in the pedons belonging to these new taxa. For technical taxonomic reasons, and based on a similar distinction of existing taxa at the great group level, it is recommended to use the formative element "kandi" for the deeply developed LAC pedons, and "kanhaplo" for the less deep pedons. To a great measure, these two kinds of LAC great groups are parallel to the present "pale" and "hapl" great groups distinguished in various suborders of Alfisols and Ultisols. Where the LAC properties have a lesser priority in the naming of great groups, such as is the case for existing "plinth" great groups, kandic subgroups are to be introduced.

2. Diagnostic criteria

The argillic horizon. Soil Taxonomy requires Alfisols and Ultisols to have an argillic horizon, as discussed and defined on pp. 19-27. An argillic horizon has to contain illuvial layer-lattice clays, and must have either a specific clay increase, compared to an eluvial horizon, or clay skins (or oriented clay bridges), or both (p. 27, Summary of properties). Problems arise in many pedons of LAC Alfisols and Ultisols where clay skins cannot irrefutably be identified in the field and/or by microscopic study of thin sections. In many cases such supposed argillic horizons have most of the characteristics of an oxic horizon (Soil Taxonomy, pp. 36-41), and such pedons would be classified as Oxisols were it not that a clear, non-sedimentary increase of clay content is found. Similar difficulties are met in the distinction of certain LAC Alfisols and Ultisols from Inceptisols dominated by low activity clays. These cases are, however, much less frequent.

While the reasons for this apparent lack of clay skins as a result of illuviation are not altogether clear, it appears that the high biological activity under tropical humid and subhumid conditions may be involved. Destruction of clay skins by termites, for instance, is an established fact. Also, other mechanisms for the loss of clay from the "eluvial horizon" may be operative, such as selective erosion of the clay-sized particles from the surface layers, or a complete breakdown of layer-lattice clay and leaching of its constituents without corresponding enrichment in the horizons below (appauvrissement and ferrolysis). In all these cases the process of clay loss from a surface horizon has been, or still is, active, resulting in pedons with a subsurface horizon answering the textural requirements for an argillic horizon, but with no or unclear clay skins or clay bridges between sand grains.

In order to facilitate the taxonomic distinction between Oxisols and LAC Inceptisols on the one hand, and LAC Alfisols and Ultisols on the other, a new diagnostic soil characteristic has been proposed. In cases discussed above, use can be made of the presence of a "finer textured subsurface horizon" (tentatively the abbreviation FTSH is used), which is defined in Appendix 1. It should be pointed out that the FTSH does not replace the argillic horizon in diagnosing LAC Alfisols and Ultisols. It is only used in such cases where a clear textural horizon differentiation is present, without a corresponding observable presence of clay skins or clay bridges between sand grains. Although the definition of the FTSH is given in general terms, we cannot go beyond the recommendation that it is used for the pedons and taxa falling under the mandate of ICOMLAC.

Charge properties of LAC--the CEC criterion. The clay fraction of the LAC Alfisols and Ultisols is dominated by 1:1 lattice clays (mainly kaolinite) and/or by (hydr)oxide of Fe (mainly goethite and hematite), with frequent presence of Al hydroxide (gibbsite). Ideally, the LAC property should, therefore, be measured by the quantitative determination of the mineralogy of the clay fraction. In reality, reliable routine methodology for such an analysis does not exist, so that the mineralogy of the clay fraction at present cannot be more than an accessory property of "low activity."

Charge properties of low activity clays are anything but uniform. At most, it can be stated that the permanent charge of these clays is low, though (as in the case of kaolinite-dominated soils) usually measurable. Relatively speaking, the variable (or pH-dependent) charge is moderate to high, especially in cases where lattice layered silicate clays are scarce. Purposely, allophanes and related minerals, which have a high negative charge at higher pH values, have been excluded from the committee's LAC taxa, so that the newly proposed Andisol order, as well as andic subgroups are excluded from our consideration. Many accessory properties to "low activity" of the clay fraction, as defined here, have been studied or are under study: plasticity index, swelling potential, anion adsorption and phosphate fixation, aggregate stability, chemical dispersion, ZPC and delta pH, silica-sesquioxide ratio, degree of weathering, and others. Whereas some of these properties show a reasonable degree of covariance with the low permanent charge (and, hence, the low CEC), no firm correlation can be presented. Thus, at best, most of the properties named may provide supporting evidence of low activity without by themselves, or even in combination, being usable as indisputable diagnostic properties of the LAC taxa. For these reasons, ICOMLAC is following the present procedure of Soil Taxonomy for characterizing the charge properties of the clay fraction, notably by determination of the CEC of this fraction (in meq/100 g clay).

Soil Taxonomy uses, within the Alfisol and Ultisol orders, various methods of analysis for the determination of CEC and its derived values (base saturation):

--CEC by sum of cations (5A3a)*

--CEC by NH_4OAc at pH 7 (5A1a, 5A6a)

--Cation retention from NH_4Cl

*Method codes refer to Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples, Soil Conservation Service, 1972.

ICOMLAC proposes to drop the latter, and to add:

--ECEC: sum of extractable bases (5B4a) plus 1N KCl-extractable Al, at the pH of the soil.

The CEC values are expressed in meq/100 g clay; the base saturation is in percent.

The CEC NH_4OAc is used for the distinction of LAC Alfisols and Ultisols from the other taxa of these orders as follows:

Kandi taxa of Ultisols should have a CEC NH_4OAc of <16 meq/100 g clay in the upper 50 cm of an argillic horizon or of an FTSH.

Kanhapl taxa of Ultisols should have a CEC NH_4OAc of <16 meq/100 g clay in the major part of an argillic horizon or of an FTSH.

For the kandi and kanhapl great groups of Alfisols, the diagnostic value of the CEC NH_4OAc is 24 meq/100 g clay. The depth requirements, mentioned above for Ultisols are the same for Alfisols.

ECEC was introduced as an alternate to CEC NH_4OAc. For Ultisols, the ECEC should be less than 12 meq/100 g clay at the diagnostic depth; for Alfisols, this value is 16 meq.

ICOMLAC recognized the fact that the CEC criterion is not an ideal one. CEC NH_4OAc analysis is laborious, and subject to many sources of error, especially at the low values common for the LAC taxa. The advantages are that it is a common and internationally used method, and that the pH dependency of the data is eliminated by introducing one reference pH (i.e. pH 7). This immediately indicates the disadvantage of ECEC, which indeed changes where soil management alters the pH of the diagnostic horizons (e.g. by deep liming). Thus, a soil which is classified as a (marginal) LAC taxon may "lose" its LAC property by soil management when the ECEC is used as the exclusive diagnostic value. Clearly, more research has to be done on current and alternative CEC (and ECEC) determinations, and on accessory properties to fit the requirements for a reliable diagnosis of LAC taxa.

Soil temperature. In the course of ICOMLAC's discussions it was decided to recommend that the criteria used for distinguishing the present "trop" great groups of Alfisols and Ultisols should not be used in the classification of LAC taxa at the great group or subgroup level. Whereas most LAC pedons have a warm iso-soil temperature regime, some of them have a non-iso regime. This distinction, important for management, will be made at the family level.

Fe and Al in the fine earth and clay fractions. Dominance of Fe (hydr)oxides or Al hydroxides (gibbsite) in the fine earth and in the clay fraction has important soil genetic and morphological implications, and is important also from a soil management point of view. Soils high in such compounds have, among other characteristics, a more stable structure, a greater microporosity, and a soft or friable consistence, irrespective of moisture content. Due to the dominance of compounds with a relatively high ZPC over lattice layer silicate clays, such soils have often a relatively high anion "fixing" capacity (e.g. of phosphorus). Other properties, as for instance the high specific surface of clay-sized, "active" Fe (hydr)oxides are now being studied.

Under discussion in the framework of ICOMLAC is the desirability of distinguishing the LAC pedons with the above-mentioned properties at the great group level. A good portion of pedons classified under the present "rhod" great groups and rhodic subgroups have these properties, but the criteria used for the "rhod" concept are fundamentally different, and not all pedons belonging to "rhod" taxa have the above properties.

No definite recommendations on this subject can be made at the present time.

3. Relations to existing taxa--great soil groups keys

Two sets of relationships of LAC taxa with other taxa of Soil Taxonomy had to be established. Firstly, a boundary had to be defined between LAC taxa of Alfisols and Ultisols with Oxisols and (LAC) Inceptisols. Secondly, the place of the LAC taxa in the existing great soil group keys of Alfisols and Ultisols was to be established.

Following is a summary of the proposals for which agreement was reached in ICOMLAC.

Limits between LAC Alfisols and Ultisols and soils of other orders. To distinguish LAC Alfisols and Ultisols from Oxisols, the LAC Alfisols and Ultisols must have one or both of the following:

--an argillic horizon with clay skins discernible both in the field and in thin sections;

--an FTSH and the overlying horizon with <40 percent clay.

To distinguish LAC Alfisols and Ultisols from LAC Inceptisols, the LAC Alfisols and Ultisols must have one or both of the following:

--an argillic horizon;

--an FTSH.

To distinguish LAC Alfisols and Ultisols from LAC Mollisols, the LAC Alfisols and Ultisols must not have a mollic epipedon and an oxic horizon. (The last limit definition is tentative.)

Placing LAC Alfisols and Ultisols in the great soil group keys. Ranking of the LAC great groups varies with suborder, but in principle they should have a higher ranking than the existing "Trop," "Pale," "Rhod," "Hapl(o)," "Ochr," and "Umbr" great groups. They should have a lower ranking than the existing "Plinth(o)," "Natr," "Dur," "Fragi," "Fragloss," "Gloss," "Alb," "Sombri," "Agr," and "Ferr" great groups. Where LAC pedons occur in the latter great groups, they will be distinguished at the subgroup level. This will commonly be the case for the "Plinth(o)" great groups, but rarely or not for most of the others.

4. Subgroups of LAC taxa of Alfisols and Ultisols

Many of the subgroups defined in Soil Taxonomy for the existing great groups of Alfisols and Ultisols will also occur in the newly proposed LAC great groups. Descriptions of the typic subgroups must be made based on our factual knowledge of subgroups recognized and described, and of subgroups of which the existence can be predicted with a great degree of probability.

The present great soil group keys of Alfisols and Ultisols would be modified as follows:

HA: AQUALFS (Soil Taxonomy, p. 109)

HAA. .... Plinthaqualfs
HAB. .... Natraqualfs
HAC. .... Duraqualfs
HAD. .... Fragiaqualfs*
HAE. .... Glossaqualfs*
HAF. .... Albaqualfs*
HAG. .... Kandiaqualfs
HAH. .... Tropaqualfs
HAI. .... Umbraqualfs
HAJ. .... Ochraqualfs

*placement different from a previous proposal

(At present no Kanhaplaqualfs are proposed.)

HC: ULTALFS (Soil Taxonomy, p. 138)

HCA. .... Durustalfs
HCB. .... Plinthustalfs
HCC. .... Natrustalfs
HCD. .... Kandiustalfs
HCE. .... Kanhaplustalfs
HCF. .... Paleustalfs
HCG. .... Rhodustalfs
HCH. .... Haplustalfs

HE: UDALFS (Soil Taxonomy, p. 125)

HEA. .... Agrudalfs
HEB. .... Natrudalfs
HEC. .... Ferrudalfs
HEE. .... Fraglossudalfs
HEF. .... Fragiudalfs
HEG. .... Kandiudalfs
HEH. .... Kanhapludalfs
HEI. .... Paleudalfs
HEJ. .... Rhodudalfs
HEK. .... Tropudalfs
HEL. .... Hapludalfs

(A great soil group of Plinthudalfs is probably required.)

FA: AQUULTS (Soil Taxonomy, p. 351)

FAA. .... Plinthaquults
FAB. .... Fragiaquults
FAC. .... Albaquults
FAD. .... Kandiaquults
FAE. .... Kanhaplaquults
FAF. .... Paleaquults
FAG. .... Tropaquults
FAH. .... Ochraquults
FAI. .... Umbraquults

FB: HUMULTS*(Soil Taxonomy, p. 355)

FBA. .... Sombrihumults
FBB. .... Plinthohumults
FBC. .... Kandihumults
FBD. .... Kanhaplohumults
FBE. .... Palehumults
FBF. .... Tropohumults
FBG. .... Haplohumults

*Some changes are proposed in the present Soil Taxonomy to establish a better agreement with the ranking in other suborders.

FC: UDULTS (Soil Taxonomy, p. 360)

FCA. .... Fragiudults
FCB. .... Plinthudults
FCC. .... Kandiudults
FCD. .... Kanhapludults
FCE. .... Paleudults
FCF. .... Rhodudults
FCG. .... Tropudults
FCH. .... Hapludults

FD: USTULTS (Soil Taxonomy, p. 369)

FDA. .... Plinthustults
FDB. .... Kandiustults
FDC. .... Kanhaplustults
FDD. .... Paleustults
FDE. .... Rhodustults
FDF. .... Haplustults

An incomplete listing of common subgroups, besides the typic, would include: aeric (for LAC Aqualfs and Aquults), aquic (for other LAC Alfisols and Ultisols), arenic, grossarenic, plintic, and psammentic. For part of the LAC great groups, subgroups identified or to be expected would include: epiaquic, abrubtic, lithic, paralithic, fragic, petroferric, rhodic, udic, ultic, ustic, xeric, and composites of those subgroups (multiple subgroups).

The necessity of some, but by no means all, new subgroups specifically required for LAC taxa were discussed. "Acric" subgroups would be required in LAC taxa of Ultisols, for intergrades towards, respectively, Acrohumox, Acrorthox, and Acrustox. The diagnostic property to be tested for pedons of such subgroups is an ECEC of less than 2.5 meq/100 g clay in some subhorizon of the argillic horizon and/or the FTSH.

"Vadic" subgroups were proposed for such pedons which are not hydromorphic enough to be considered as an aquic subgroup, but which show moderate to strong iron segregation, frequently due to seasonal interflow-water saturation. Subgroups would be required to differentiate soils belonging to the same great groups, but which are respectively poor or relatively rich in weatherable minerals. Pedons with more than 10 percent weatherable minerals might go with a "caric" subgroup.

D. Concluding Remarks

The foregoing chapter is a review of the progress made by ICOMLAC towards fulfilling the task spelled out under its mandate. A consensus has been reached on major points, and the draft proposals are, by and large, readily for field testing. This is a necessary task which largely remains to be done, in cooperation with soil scientists from the lower latitudes. Another task which has been started, but is not completed, is implied in the aforementioned "Procedures for amendments" (SCS, 1974). The impact of each and every proposed change on the definition of all taxa that will be affected, must be described. Because the modifications that ICOMLAC wishes to propose are major ones, this task is still a considerable one.

Appendix 1

Finer Textured Subsurface Horizon (FTSH)

Many soils have subsoil clay contents greater than in their surface horizons. Many such soils are recognized as having argillic or natric diagnostic horizons. However, there are many soils where the genetic processes for forming a higher clay content in the subsoil cannot be agreed upon by pedologists. Clay skins are not readily evident to indicate formation by the lessivage process. Several alternative processes may create this morphological feature. It is possible that clay in the surface horizon may have been removed from the soil by erosion. Certainly much of the clay in the subsoil has been formed in situ by weathering from larger sized primary minerals. Also, it is possible that in many soils, especially those formed in transported materials, textural lithologic discontinuities may be present between the topsoil and the subsoil but evidence for such discontinuities is extremely difficult to establish because of extensive weathering and other pedogenic processes. While it is not desirable to include in this definition finer subsoil textures that are clearly the result of fluvial activity, as evidenced by geogenetic fine layering or by irregular organic matter contents with depth, it may include subsurface horizons where a fluvial origin is suspected providing the horizon has granular, single grain, or blocky structure or is massive or structureless.

Whereas these features can be determined from the examination of an individual pedon, it is often prudent to examine several pedons in similar geomorphic settings to determine the lateral continuity of finer textured subsoil horizons. Specific diagnostic limits of a finer textured subsurface horizon should include:

--thickness of the FTSH;

--rate of clay increase with depth;

--amount of clay increase; and

--depth of the FTSH.

Thickness

An FTSH should be at least 30 cm thick in the absence of a lithic, paralithic or petroferric contact, or should be at least 15 cm thick immediately above such a contact.

Rate of clay increase

The diagnostic increase in clay from an overlying horizon to the FTSH is reached within a vertical distance of 30 cm or less.

Amount of clay increase

The FTSH contains more total clay than the overlying horizon as follows:

(a) If any part of the overlying horizon(s) has less than 20 percent total clay in the fine earth fraction, the FTSH must contain at least 7 percent more clay.

(b) If the overlying horizon(s) has more than 20 percent total clay in the fine earth fraction, the ratio of clay in the FTSH to that in the overlying horizon(s) must be 1.4 or more, or the FTSH must contain at least 16 percent more clay.

Depth of the FTSH

By convention, a minimum and a maximum allowable depth is set, between which the upper boundary of an FTSH should fall in order for the horizon to be diagnostic. To exclude very thin coarser textured surface horizons that are easily destroyed by cultivation practices such as plowing, the upper part of the pedon should be mixed to a depth of 18 cm for the determination of its clay content.* This sets the minimum depth of the upper boundary of a FTSH at 18 cm. In practice, comparisons are usually of the mixed sample of the upper 18 cm and the sample at a depth from the surface of 43-48 cm, or between the top and bottom of 30 cm increments further down the pedon.

By convention, the maximum allowable depth of the upper boundary of an FTSH is made to depend on the clay content and particle size class of the overlying layers or horizons as follows:

1. if the clay content is 20 percent or more, the upper boundary should occur at less than 100 cm from the surface;

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*For some undisturbed pedons under continuous pasture or natural vegetation, the requirement for mixing the upper 18 cm is waived if an abrupt textural change occurs between 5 and 18 cm depth.

2. if the clay content is less than 20 percent, and the particle size class of part or all of the upper 100 cm is finer than sandy or sandy skeletal, the upper boundary should occur at less than 125 cm from the surface;

3. if the particle size class of the upper 100 cm is sandy or sandy skeletal (the texture is sand or loamy sand), the upper boundary should occur between 100 and 200 cm from the surface in the major part of the pedon.

IV. Rwanda Workshop

The Kandic Horizon as a Diagnostic Subsurface Horizon

F. R. Moormann and S. W. Buol

A. Introduction

Perhaps the most severe classification problem for soils in which low activity clays dominate is the placement in Soil Taxonomy of pedons with a subsurface horizon that fulfills the textural requirements for an argillic horizon (Soil Taxonomy, pp. 19-27), but the main accessory property, i.e. clay skins in at least part of the argillic horizon are so weakly expressed that consistent quantification by either field or laboratory procedures is doubtful.

This problem has permeated the discussions of ICOMLAC, as witnessed by most of the committee's circular letters, as well as by the summaries of discussions of the first and second International Soil Classification Workshops. As a consequence of discussions in Malaysia and Thailand, a working hypothesis was introduced whereby a finer textured subsurface horizon (FTSH) with precisely defined limits is to be used as a diagnostic property for the purpose of distinction between low activity clay (LAC) Alfisols and Ultisols on the one hand, and Oxisols and LAC Inceptisols on the other. Subsequently the concept of the FTSH. has been tested while refining the definition and proposing "kandic horizon" as its name.

It should be noted that the problem of recognizing an argillic horizon based on the presence of clay skins is not limited to the LAC taxa falling under the mandate of ICOMLAC and ICOMOX. Indeed, this problem is recurrent in the literature, as may be seen from a recent review and study by McKeague et al (1981). Nevertheless, the difficulties of using the argillic horizon concept in classification are clearly multiplied in many of the LAC pedons that are in

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close spatial association with pedons that have oxic horizons. Difficulties are therefore particularly common in udic to perudic, isothermic, or warmer iso-soil temperature regions.

B. Genesis

A kandic horizon is a subsurface horizon with a significantly finer texture than the overlaying horizon or horizons. The higher clay content of the kandic horizon cannot, by current macro- and micro-morphological diagnosis, be traced to the subsurface accumulation by illuviation of layer-lattice clays. By convention, the clay fraction of a kandic horizon is composed predominantly of 1:1 lattice layer silicates, mainly kaolinite, with varying amounts of oxy-hydroxydes of Fe and Al.

The textural differentiation of pedons with a kandic horizon may be the outcome of one or more processes acting simultaneously or sequentially, affecting the surface horizons, the subsurface horizons, or both, of the mineral soil. These processes are not all clearly understood and agreed upon. Those that are considered most important can be summarized as follows:

1. Clay eluviation and illuviation.
   In soils with a kaolinitic and/or oxidic mineralogy of the clay fraction, evidences of illuviation of clay-sized particles are frequently absent. Specifically, clay skins which are considered concomittant to the illuviation process can be completely absent. Often they are present only at depths below or in quantities less than the limits considered diagnostic for an argillic horizon (Soil Taxonomy, pp. 25 and 38).

   The absence of diagnostic clay skins may be due to a lack of orientation of the clay-sized particles during the eluviation-illuviation process. This is particularly so where a considerable portion of the clay fraction consists of Fe oxy-hydroxydes. More often, however, clay skins that may have formed as part of the early genesis of the kandic horizon may have disappeared under the environmental conditions in which kandic horizons are found. Biological activity of roots abundant in udic regimes may be one cause, but the main cause appears to be the activity of the soil fauna. Thorough mixing of the soils mass by termites and ants and, to a lesser extent, by earthworms, will cause the partial or total disappearance of clay skins over time and to a considerable depth, e.g. more than 150 cm in soils on permeable, well drained formations.

A considerable proportion of soils with a kandic horizon, of which an illuvial origin is probable, is found on old surfaces, where the illuviation process may no longer be operative, or at least acting so slowly that mixing by soil organisms or deformation by dessication pressures easily overtake the formation of clay skins. Characteristic for such conditions is the short-distance spatial variability in the occurrence of illuvial clay skins. As a result, they may be found in some pedons but not in other nearby pedons which otherwise have the same profile morphology. Even within the same horizon of a single pedon, some peds may have clay skins while others do not.

2. Clay destruction in the epipedon.
The weathering of lattice-layered silicates is a process which may lead to the relative loss of clay-sized particles from the pedon. This loss is more from the upper horizon(s) where weathering processes are most intense. Under superficially hydromorphic conditions, this process can be relatively fast.

Slow clay destruction with subsequent elimination of bases and some silica (ferrallitization) is a process particularly enhanced by high surface soil temperatures in well drained soils. Because this process affects superficial horizons to a greater degree than horizons deeper in the pedon, a vertical textural differentiation will occur in time. The relatively coarser residual material at the surface can, due to biological action, be mixed with the underlying material, thus giving rise to a gradual increase in clay content from the surface down. Whereas this process is slow, its effects will be mainly noted on old to very old stable surfaces.

3. Selective erosion.
Raindrop splash and subsequent surface-erosion cause colloidal humus and the finest soil particles to be moved further downslope than the coarser

fractions. Eventually, part of the fine fraction may be eliminated from sloping polypedons, leaving a coarser surface material. Mixing as by plowing or biological activity may cause the whole surface horizon to become relatively coarser textured. The speed of this process depends on many factors, but in climates with highly erosive rains, on soils with incomplete or absent plant cover, it may be very rapid. Coarser surface soil textures can frequently be measured in run-off plots within a few years. The superficial oblique movement of clay downslope seems to be widespread and selective erosion probably is a major process leading to textural differentiation in older cultivated lands, even if cultivation is intermittent as under shifting cultivation.

The process certainly is not exclusive to LAC soils. However, areas dominated by LAC soils frequently coincide with areas that have erosive rains so that textural differentiation due to selective erosion is a common occurrence. In warm ustic moisture regimes with high intensity rainstorms at the onset of the rainy season, selective erosion on soils without a protective plantcover is widespread.

4. Sedimentation of coarser textured surface materials.

In stratified parent materials, coarser materials may overlie finer textured strata. Most commonly such a textural suite may be found in flood plains or on lower concave aspects of slopes. The young sedimentary nature of the coarser textured surface material is often identified by clear micro stratification and the finer textured subsurface layers should not be equated with a kandic horizon. However, in other landscape positions lithological discontinuities occur which may consist of a coarser material without micro stratification overlying a finer textured stratum. If the finer textured stratum fulfills the requirements of the kandic horizon, defined below, there is no known way to exclude it from the definition of this horizon. In fact, lithological discontinuities are now known to occur in many of the soils of the intertropical zone and in many cases the superficial material is coarser textured than the underlying stratum. In sloping land, for instance, surface soil material which lost part of its clay due to one of the processes described under 1.-3. may move downslope so that the coarser textured surface layers in a given pedon may not have formed in situ.

C. Biological activity

Reworking of soils by earthworms, termites, and ants is often cited as a cause for the development of coarser textured surface soils. Detailed studies in this respect do not corroborate this contention and the materials brought to the surface by these organisms is finer textured because of a relatively lower content of the coarser sand fractions and of a higher clay and fine silt content. In termite hills, for instance, the clay content is generally higher than that of the surrounding surface soils because the material is largely derived from the finer textured subsoil.

In summary, it can be stated that the kandic horizon is almost always polygenetic and at least due in part to its old age it is not possible to quantitatively determine the share of each of the processes contributing to its formation.

D. Significance to soil classification

The kandic horizon plays, by definition, only a role in the classification of soils in which the clay fraction is formed predominantly by low activity clays. In these LAC taxa the use of the argillic horizon to distinguish Alfisols and Ultisols from Oxisols and Inceptisols loses much of its meaning, because the main accessory properties of this horizon are either partially or completely absent or they are so weakly or irregularly detectable that they cannot serve as appropriate quantitative differentiae. Yet, among these LAC soils, many are found that have lost clay from their superficial horizons, leading to a vertical textural differentiation which cannot be distinguished from others in which an argillic horizon has been recognized. Textural differentiation in LAC soils is, by itself, believed to be sufficiently important for the understanding of soil development and interpreting their management properties that it should be recognized at high level of the classification. In clayey textured soils, the textural differentiation loses much of its genetic and practical importance. Hence, by convention, the kandic horizon is not used as a diagnostic horizon where the clay content is 40 percent or more in the upper horizons of the solum. Genetically, the presence of kandic horizons indicates a high degree of weathering of the mineral soil material. This is mostly related to the common occurrence of soils with a kandic horizon on old surfaces where weathering has taken place under warm climatic conditions with moderate to high precipitation during the rainy season(s). However, not all soils with a kandic horizon are old in the present landscapes: part of them have formed in pre-weathered sediments of various age.

The high degree of weathering observed in the kandic horizon pertains to the clay fraction in which 1:1 lattice layers and/or oxyhydroxydes of iron dominate, with or without gibbsite. The composition of the coarser fractions, more in particular the 20-200 micron fraction does not necessarily always reflect this stage of weathering. Whereas the content of silt and sand sized weatherable minerals in the kandic horizon is often low, this is not always the case, most notably in kandic horizons of soils developed on weathering products of crystalline rocks in landscapes which during the late Pleistocene period have undergone rejuvenation due to erosion.

In summary, the main significance of the kandic horizon is taxonomic, i.e. to distinguish in the field between soils with a distinct clay increase with depth (Alfisols and Ultisols) and soils with no or only a weak clay increase (Oxisols and LAC Inceptisols). However, certain genetic scenarios are indicated by its identification.

E. Identification

The kandic horizon, by definition, is a subsurface horizon, underlying one or more coarser textured horizons. The overlying horizons may normally be equated with an epipedon although occasionally the upper part of the kandic horizon may be the lowest part of an attenuated mollic, umbric, or ochric epipedon. If a diagnostic clay increase falls within such an epipedon it is the increase that is determinant, and not the other characteristics. The coarser overlying horizons should be of sufficient magnitude that they can be recognized as such, when mixing the superficial soil layers to a depth of 18 cm, as in plowing (In some soils under natural vegetation this requirment may be waived, provided the increase of clay content conforms to that of an abrupt textural change [Soil Taxonomy, p. 47] and takes place at a depth of not less than 5 cm).

The upper boundary of the kandic horizon normally is clear or gradual. A computer analysis of 45 low activity clay soils with an increase of the clay content as required for a kandic horizon indicated that in 15 profiles the required clay increase took place within 3.5-6.5 cm (clear boundary) while in 30 the increase occurred within 6.5-12 cm (gradual boundary). The distinctness of the clay increase in isotropic parent materials is therefore a reasonable field characteristic to separate the kandic from the oxic or cambic horizon, where the clay increase is commonly absent or diffuse.

In anisotropic parent materials, the transition to the kandic horizon is mostly clear or abrupt, and is frequently marked by the presence of a stoneline or a gravelly layer. The material overlying this gravelly layer may have been deposited or it may have been brought to the surface by biological activity (termites, ants, earthworms); it should, however, fulfill the requirement that it contains less clay than the materials of the underlying kandic horizon.

The probability that the differentiation between overlying coarser material and a finer textured subsoil is an exclusive lithological phenomenon increases with the depth at which the transition to the kandic horizon takes place. Moreover, the influence of the kandic horizon on management properties of the soil also decreases with the depth of this transition.

For this reason, the top of the kandic horizon should be found at a reasonable depth which, by convention is defined as follows:

--If the clay content of the overlying, coarser textured horizon(s) is 20 percent or more, the upper boundary of the kandic horizon should occur at less than 100 cm from the surface.

--If the clay content of the overlying, coarser textured horizon(s) is less than 20 percent, and the particle size class (of part or all of the upper 100 cm) is finer than sandy skeletal, the upper boundary of the kandic horizon should occur at less than 125 cm from the surface.

--If the particle size class of the upper 100 cm is sandy or sandy skeletal (the texture is sand or loamy sand), the upper boundary of the kandic horizon should occur between 100 and 200 cm from the surface in the major part of the pedon.

Other field characteristics of kandic horizons are not normally diagnostic, since these horizons may have properties of the argillic, the cambic, or the oxic horizons. Some resemble argillic horizons as regards a well developed subangular blocky texture, or the presence of bleached grains of sand and silt in the overlying coarser textured horizon(s). The ratio of fine clay (particles smaller than 0.2 microns) to total clay may be larger in the kandic horizon than in the overlying coarser horizon(s), but very few data are available.

Other kandic horizons have one or more properties of the oxic horizon and they would be called an oxic horizon but for the distinct clay increase. For the same reason, in pedons dominated by low activity clays we may find horizons which would have been called a cambic horizon but for the clay increase.

The kandic horizon is parallel or nearly so to the surface of the polypedon. If this is not the case a recent deposit of the coarser surface material should be expected.

F. Summary of Properties

The kandic horizon is a subsurface horizon in which at 50 cm below the top of the horizon or immediately above a lithic, paralithic, or petroferric contact, whichever is shallower, the fine earth fraction has an apparent NH_4OAc CEC at pH 7 of 24 meq or less/100 g clay or an apparent ECEC of 16 meq or less/100 g clay. It has the following properties that can be used for identification:

1. The presence of one or more coarser textured horizons overlying the kandic horizon is required. The minimum depth of the overlying horizons is 18 cm, after mixing as in plowing, or 5 cm if the transition to the kandic horizon is abrupt.

2. The kandic horizon contains more total clay than the overlying horizon as follows. The increase in clay content is reached within a vertical distance of 12 cm or less.

a. If the horizon overlying the kandic horizon has less than 20 percent total clay in the fine-earth fraction, the kandic horizon must contain at least 4 percent more clay.

b. If the horizon, overlying the kandic horizon has more than 20 percent total clay in the fine-earth fraction, the ratio of clay in the kandic horizon to that in the overlying horizon must be 1.2 or more, or the kandic horizon must contain at least 8 percent more clay.

3. A kandic horizon should be at least 30 cm thick as measured from its top in the absence of a lithic, paralithic, or petroferric contact, or at least 15 cm thick if such a contact is present. Excluded from the definition of a kandic horizon are finer textured lamellae, irrespective of their cummultative thickness.

4. The layers or horizons, overlying a kandic horizon should not show fine stratification, nor should they have an organic carbon content that decreases irregularly with increasing depth.

5. A kandic horizon may have clay skins but they should not be thick and continuous in all parts, and the cross section should not have more than 5 percent oriented clay, to a depth of 125 cm below the surface of the soil or 75 cm below the top of the kandic horizon whichever is deeper.

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